Geostationary Lightning Mapper for GOES-R and Beyond

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http://www.orbit.nesdis.noaa.gov/star

Lightning from a storm system extending from Argentina to southern Brazil on the evening of April 23, 2003. (Photograph from the International Space Station, NASA Image Exchange, image number ISS006-E-48196.)

STAR Science Forum

11 April 2008

WWB 707, Camp Springs, MD

Outline of Presentation

- Heritage and History
  - » NASA Optical Transient Detector (1995-2000)
  - » NASA Lightning Imaging Sensor (1997-Present)
- GOES-R Geostationary Lightning Mapper (2014)
  - » Instrument Measurement Approach
  - » Algorithms
  - » Products and Applications
  - » Cal/Val
  - » User Readiness
- Conclusions

Note: All slides are approved for public presentation

Acknowledgements

- **EOS TRMM/LIS Instrument Team**
- **GLM AWG/R3 Lightning Applications Team**
- **LMATC**

  - » Dr. Hugh J. Christian/NASA MSFC retired, UAH
  - » Dr. Richard J. Blakeslee/NASA MSFC
  - » Dr. William J. Koshak/NASA MSFC
  - » Dr. Doug Mach/UAH
  - » Dr. Robert Boldi/UAH
  - » Dennis Buechler/UAH
  - » Dr. Doug Mach/UAH
  - » Dr. Walt Petersen/UAH
  - » Dr. Dennis Boccippio/NASA MSFC
  - » Dr. Monte Bateman/USRA
  - » Dr. Bill McCaul/USRA
  - » Dr. Kevin Driscoll/UAH
  - » Dr. William Boeck/Niagara Univ.
  - » John Hall/UAH
  - » Chris Darden/HUN WWSFO
  - » Steve Zubrick/LWX NWSFO
  - » Paul Krehbiel, Bill Rison, Ron Thomas/NM Tech

GLM Overview and Heritage

Observational Requirement	LEVEL	Geo Coverage	Vert. Res	Horiz. Res	Mapping Accuracy	Msmnt Range	Msmnt. Accuracy	Refresh Rate	Data Latency
Lightning Detection	T	CONUS	Sfc to cloud top	10 km	5 km	Real Time	70-90% Detection	Contin-uous	< 1 min
Lightning Detection	T	Hemispheric	Sfc to cloud top	10 km	5 km	Real Time	70-90% Detection	Contin-uous	< 1 min
Lightning Detection	T	Mesoscale	Sfc to cloud top	10 km	5 km	Real Time	70-90% Detection	Contin-uous	< 1min

- **Provide continuous, full-disk lightning measurements for storm warning and nowcasting.**
- **Provide early warning of tornadic activity.**
- **Accumulate a long-term database to track decadal changes of lightning.**

Natural Hazards and Lightning

- Tornadoes
- Hailstorms
- Thunderstorms
- Floods
- Hurricanes
- Volcanoes
- Forest Fires

GLM Applications and Benefits

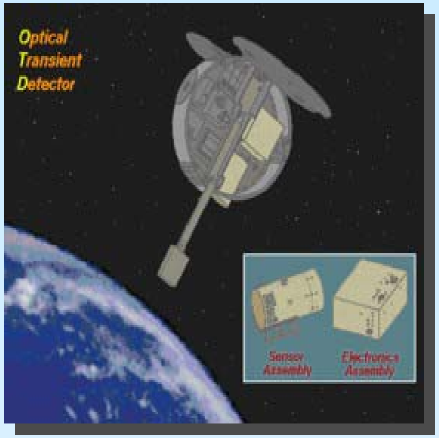
- Predict the onset of tornadoes, hail, microbursts, flash floods;
- Track thunderstorms and warn of approaching lightning threats;
- Improve airline routing around thunderstorms; improving safety, saving fuel, and reducing delays; TAFs
- Provide real-time hazardous weather information, improving the efficiency of emergency management;
- NWP/Data Assimilation;
- Locate lightning strikes known to cause forest fires and reduce response times;
- Multi-sensor precipitation algorithms (Applicable to GPM);
- Assess the role of thunderstorms and deep convection in global climate;
- Provide a new data source to improve air quality / chemistry forecasts.

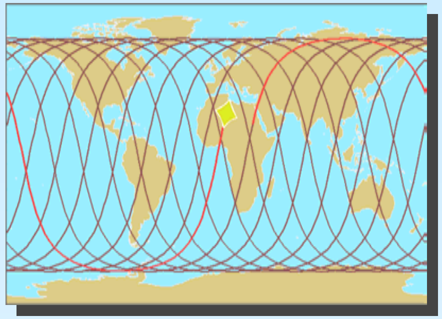
GLM Implementation Status (April 2008)

The GLM is a single channel, near-IR imager/transient detector used to measure total lightning activity over the full-disk as part of a 3-axis stabilized, geostationary weather satellite system

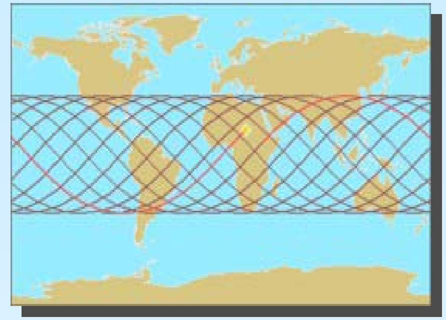
- Heritage
  - » Lightning Mapper Sensor for GOES-M
  - » NASA EOS TRMM/LIS, OTD
- NASA Lead Role for Instrument
  - » NOAA Funded
  - » RFP Released 26 July 2005
  - » Formulation Studies (3) Completed March 2007
  - » Implementation Phase Contract Valued at $96.7M Awarded to Lockheed Martin Space Systems Company December 2007
    - 1 Prototype Model
    - 4 Flight Models
  - » Kick-off Meeting February 2008, Palo Alto, CA
- NOAA Lead Role for Ground System
  - » GOES-R Risk Reduction- Science Team - August 2006
  - » Algorithm Working Group- Lightning Applications Team - June 2007
    - ATBD, Algorithm Theoretical Basis Document, 2008
    - Proxy data from NASA Lightning Imaging Sensor/TRMM and Regional Test Beds (e.g., US Lightning Mapping Arrays- North Alabama, Washington, DC, Oklahoma)

OTD LIS

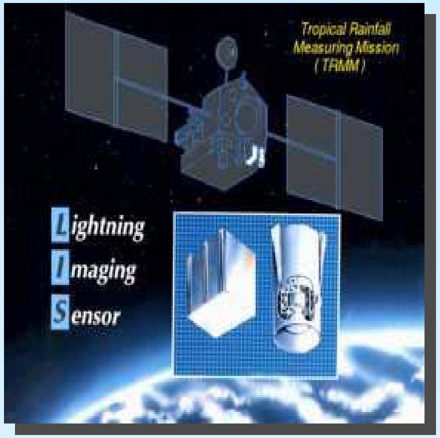




1995-2000



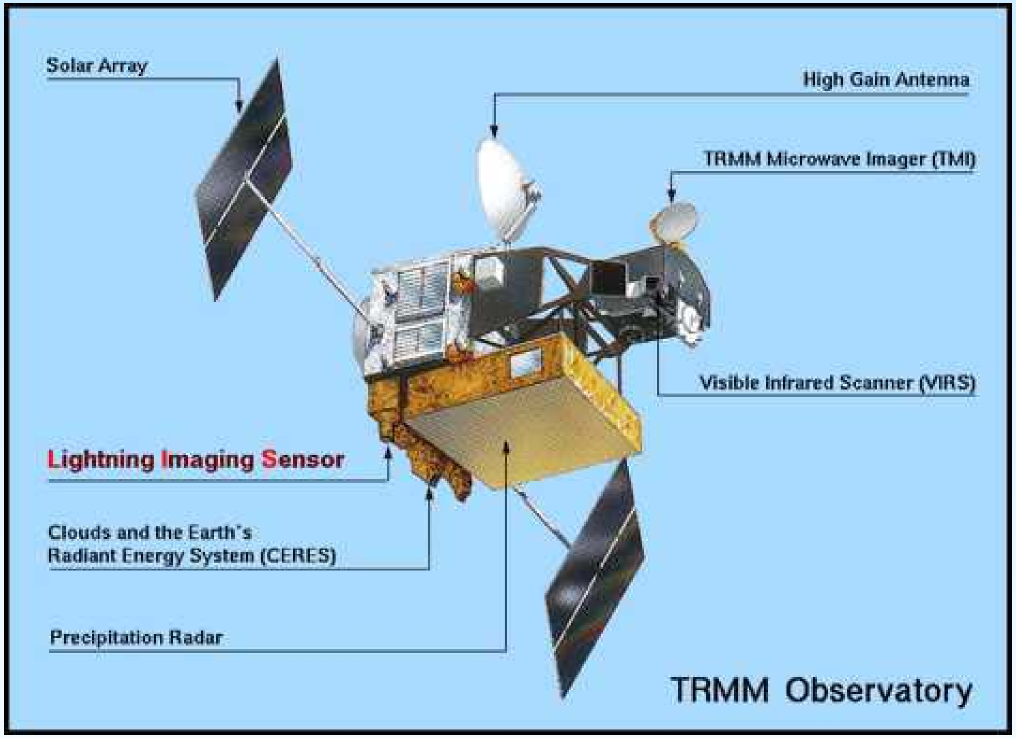
1997-Present



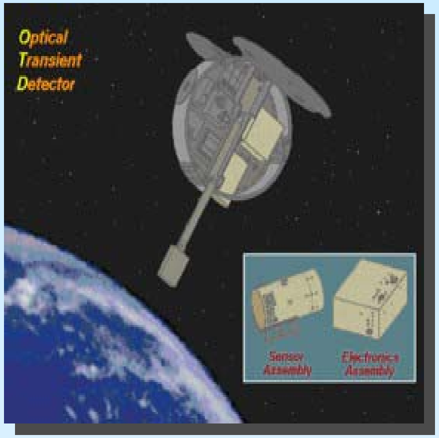
	OTD	LIS Pre-boost	LIS post-boost	GLM
Inclination	70°	35°	35°	0°
Altitude	735 km	350 km	402 km	36,000 km
FOV (across)	1253 km	583 km	668 km	Full-disk
FOV (diagonal)	1934 km	870 km	1001 km	18,000 km
Pixel FOV (nadir)	7.9 km	3.7 km	4.3 km	8 km
Pixel FOV (corner)	25.9 km	10.3 km	12.0 km	12 km
Observation time	190 s	80 s	92 s	Continuous
Orbital Period	99.5 min	91.5 min	92.56 min	1436 min

TRMM boost completed August 22, 2001

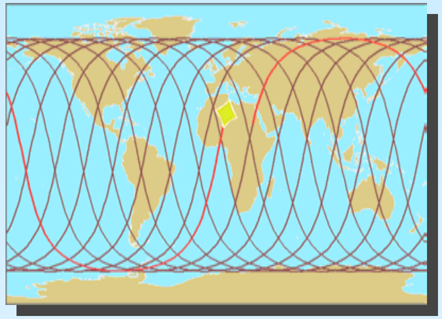
NASA Tropical Rainfall Measuring Mission



- Largest observatory built in-house at GSFC
    - Size: 16.7 ft. long, 12.1 ft. diameter, 47.9 ft. across solar array
        - Dry Mass: 5766lbs (2621kg)
        - Fuel Mass: 1962lbs (890kg)
        - Total Launch Mass: 7728lbs (3512kg)
- Stabilization: 3-axis Earth pointing 0.20 degrees
- Data rate: 200 kbps

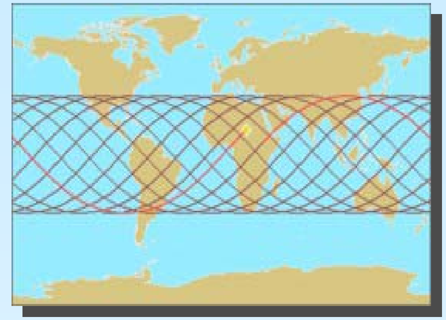


OTD

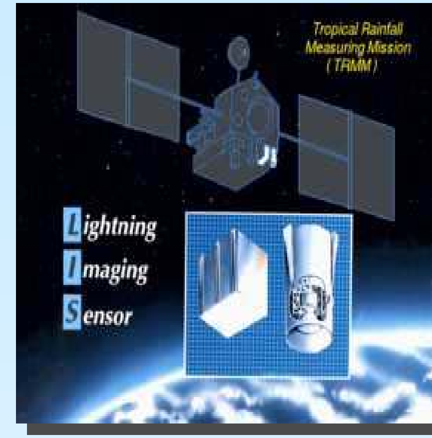


1995-2000

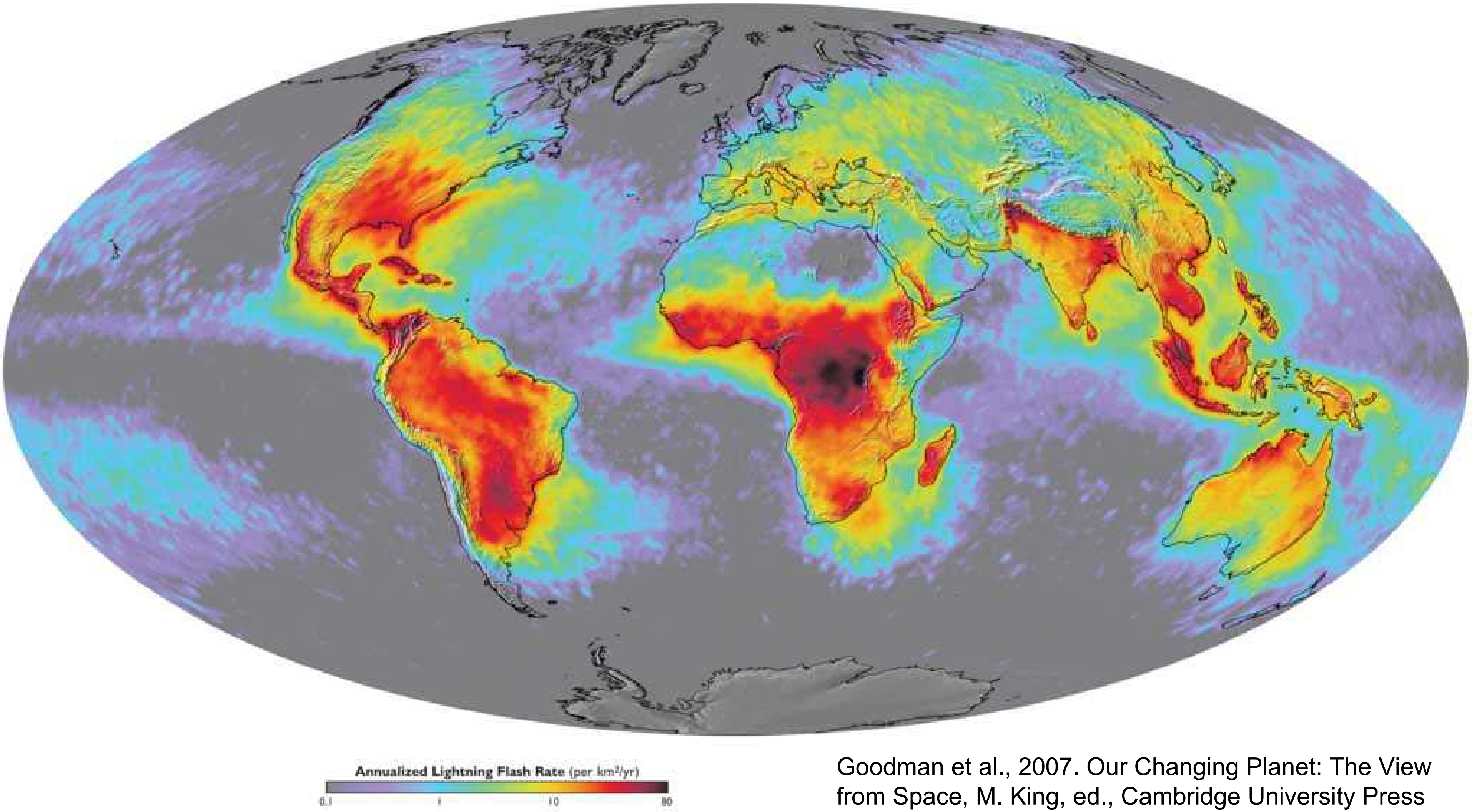
LIS



1997-Present



Global Distribution of Lightning Activity

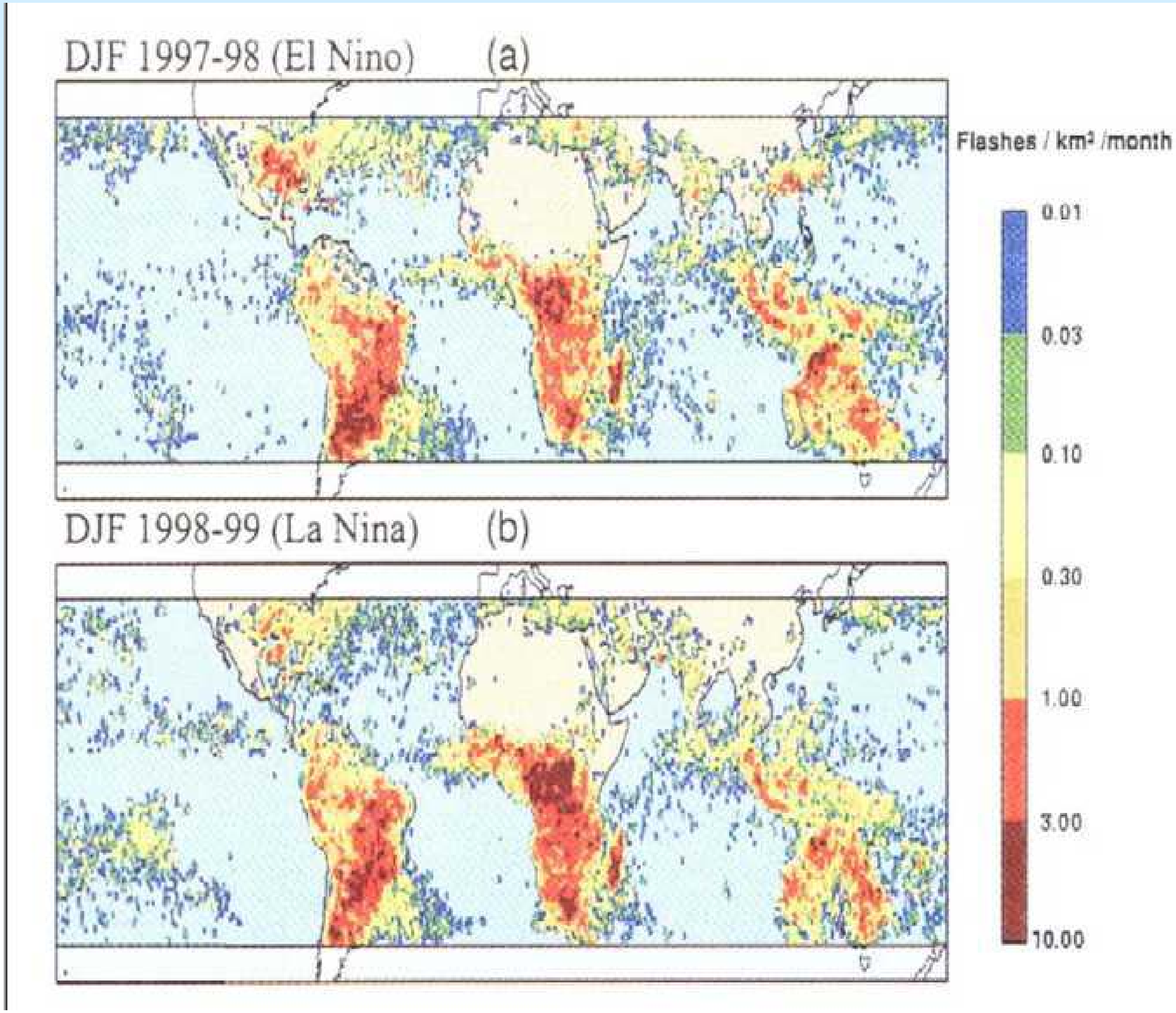


Goodman et al., 2007. Our Changing Planet: The View from Space, M. King, ed., Cambridge University Press

Mean annual global lightning flash rate (flashes km^{-2} yr^{-1}) derived from a combined 8 years from April 1995 to February 2003. (Data from the NASA OTD instrument on the OrbView-1 satellite and the LIS instrument on the TRMM satellite.)

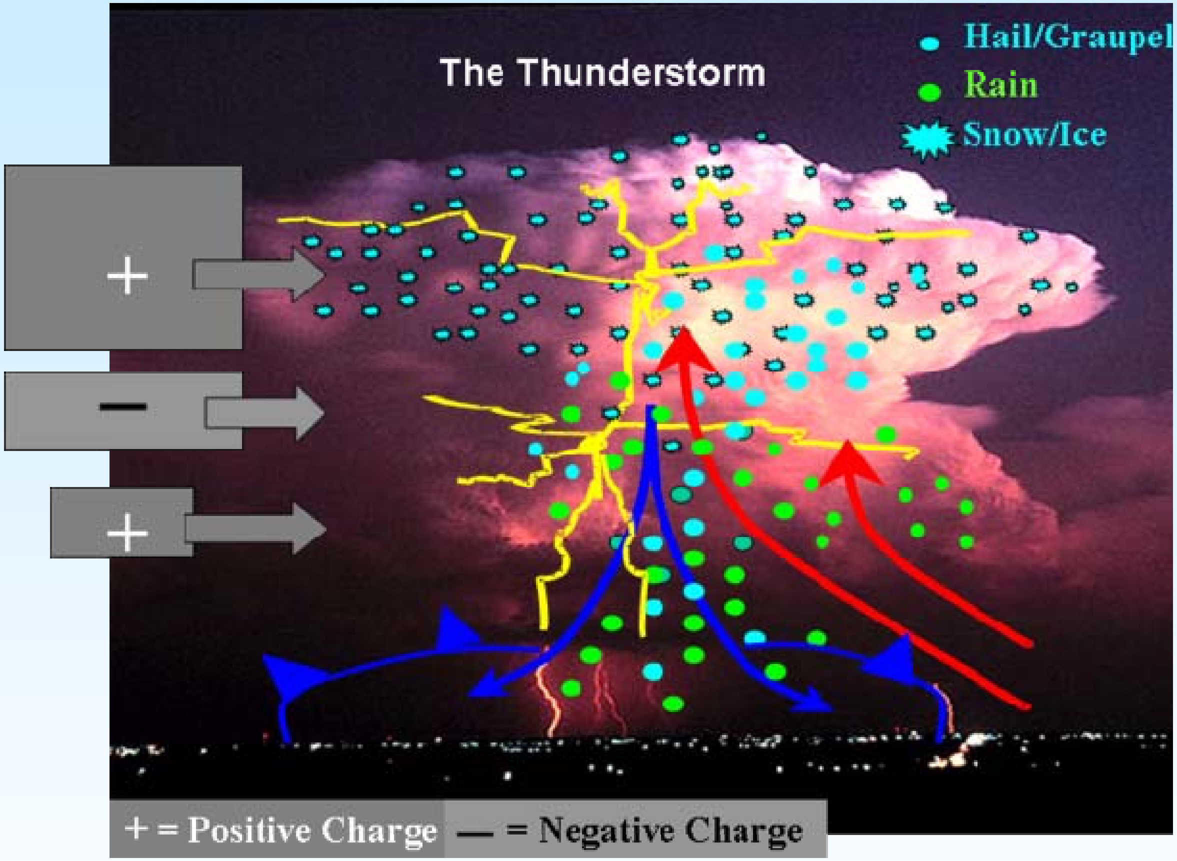
Interannual Variability of Lightning

- 100% increase in GulfMex thunderstorm activity during ENSO
- Greatest year-to-year change in global lightning activity occurs in northern GulfMex
- Nocturnal Tornadic Storms in Florida



Goodman et al., GRL, 2000

Ice and Lightning: A physically-based chain of causation……………………



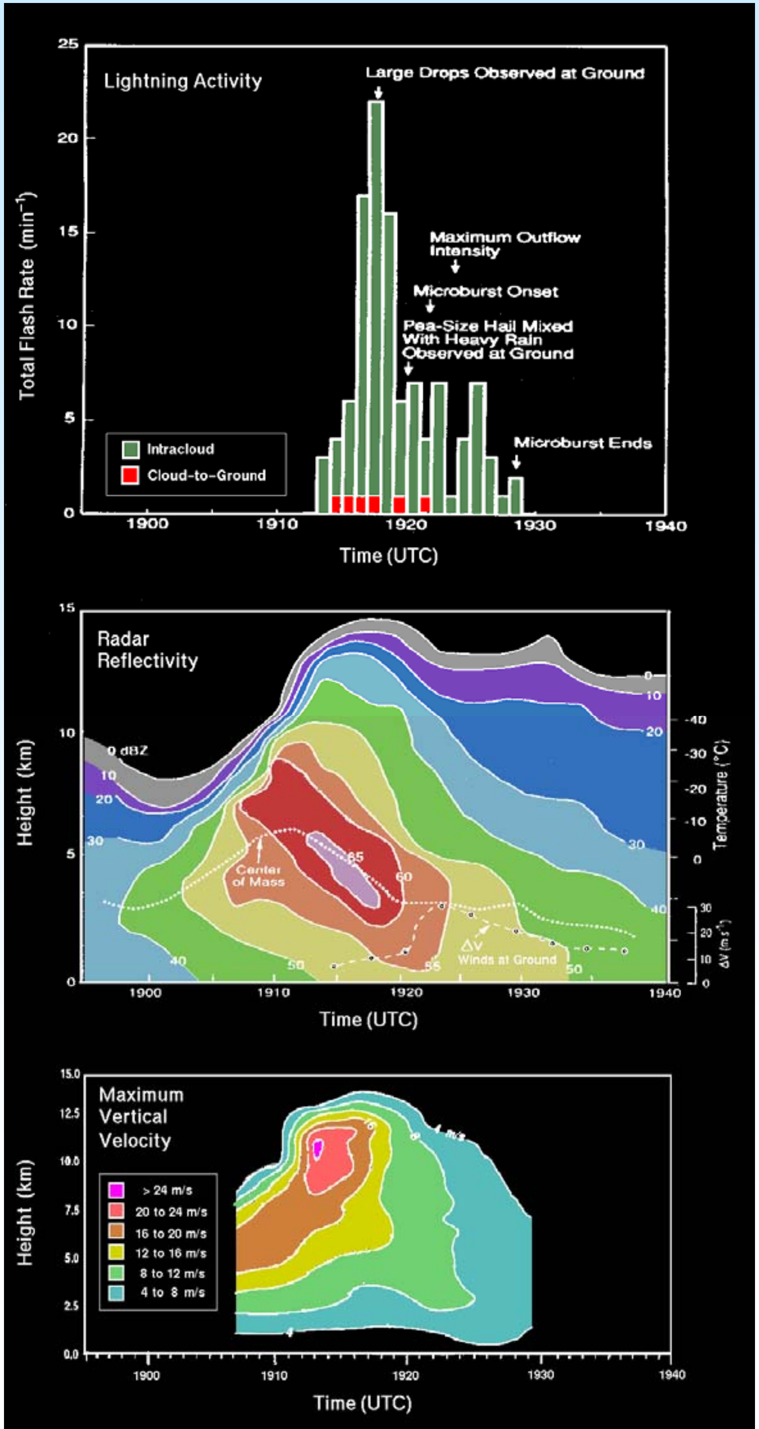
1. Strong updraft
2. Condensate
3. Deep mixed phase
4. Large numbers of coexisting precipitation-sized ice and cloud ice
5. Collisions and particle scale charge separation
6. Cloud scale relative charge separation (gravitational + advective)
7. Large electric fields
8. Lightning

Simple Hypothesis

Physics suggests that lightning flash rate should be proportional to precipitation ice mass in convection (especially in zone of active charge generation) and the proportionality should be globally regime invariant .

Lightning Connection to Thunderstorm Updraft, Storm Growth and Decay

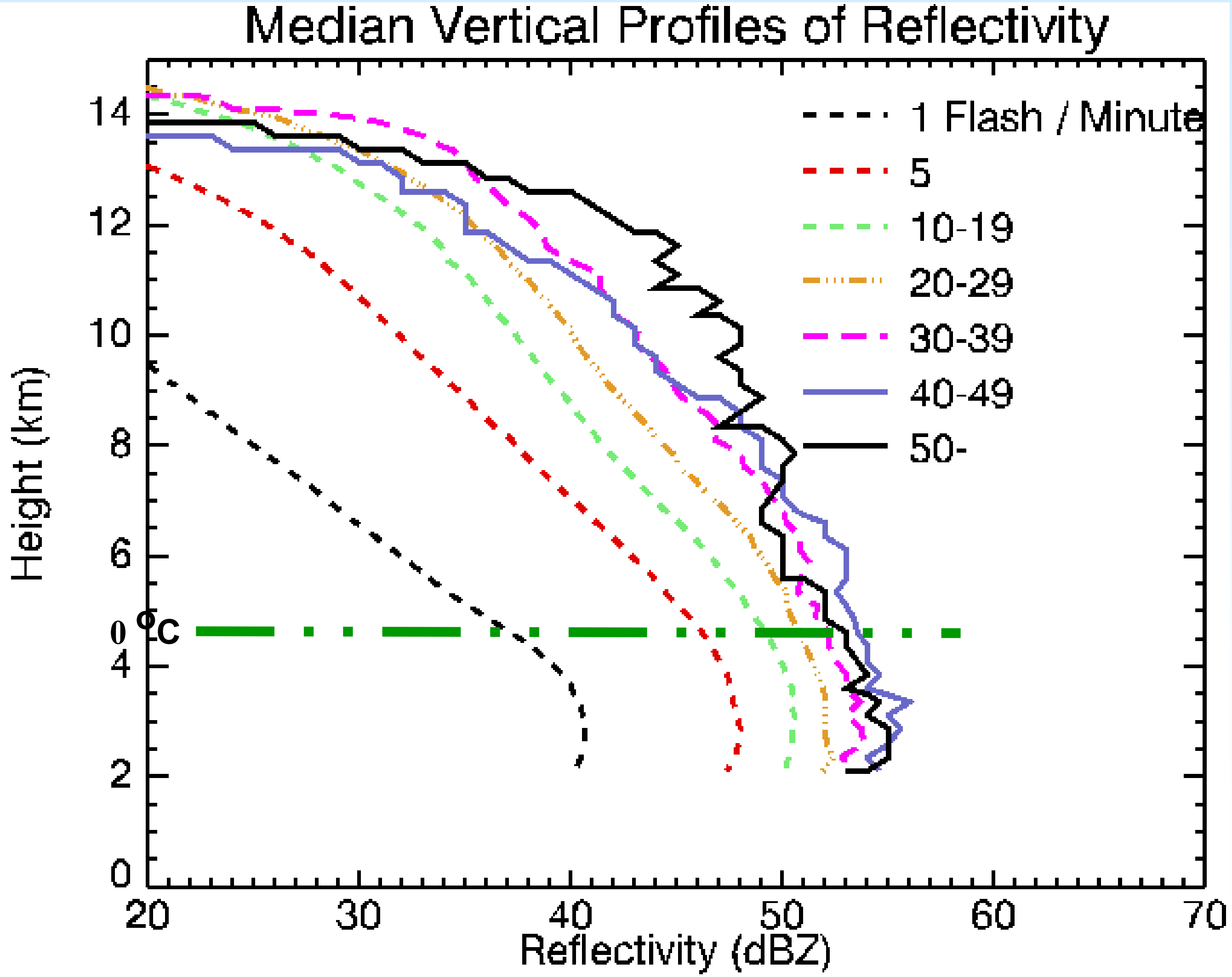
- Total Lightning —responds to updraft velocity and concentration, phase, type of hydrometeors, integrated flux of particles
- Radar — responds to concentration, size, phase, and type of hydrometeors- integrated over small volumes
- Microwave Radiometer — responds to concentration, size, phase, and type of hydrometeors — integrated over depth of storm (85 GHz ice scattering)
- VIS / IR — cloud top height/temperature, texture, optical depth



After Goodman et al., 1989;Kingsmill and Wakimoto, 1991

Flash Rate Coupled to Mass in the Mixed Phase Region

Cecil et al., Mon. Wea. Rev. 2005 (from TRMM Observations)

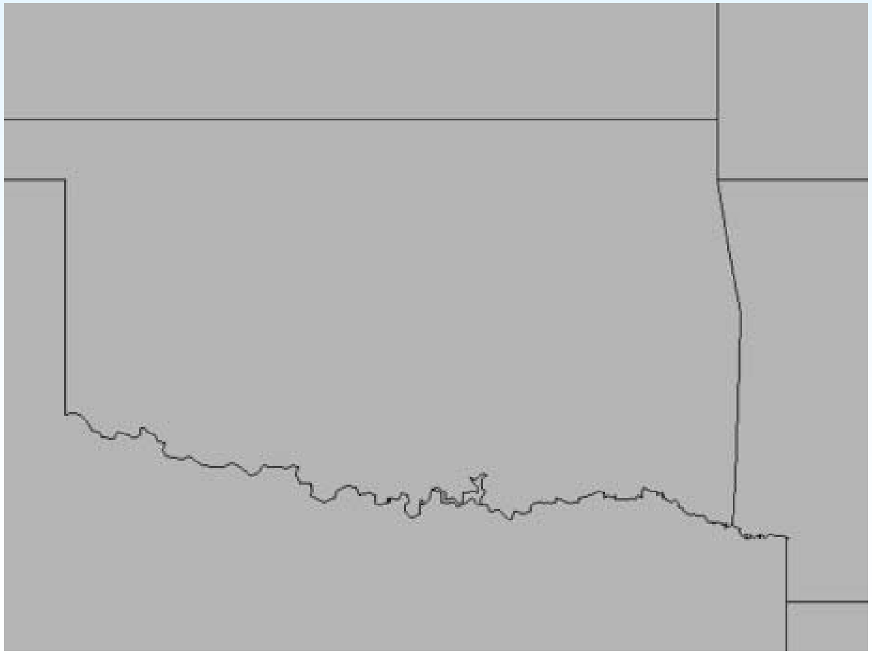


Mapping storm initiation, growth, decay

TRMM LIS-Lightning: May 1999 Stroud, OK Tornado

- TRMM provides us a huge database of paired lightning, radar, IR and passive microwave observations (training, validation)
- Over entire tropics & subtropics (generalization)
- Total lightning increases as storm intensifies – can increase lead time for warning of severe and tornadic storms

GOES-R GLM Perspective

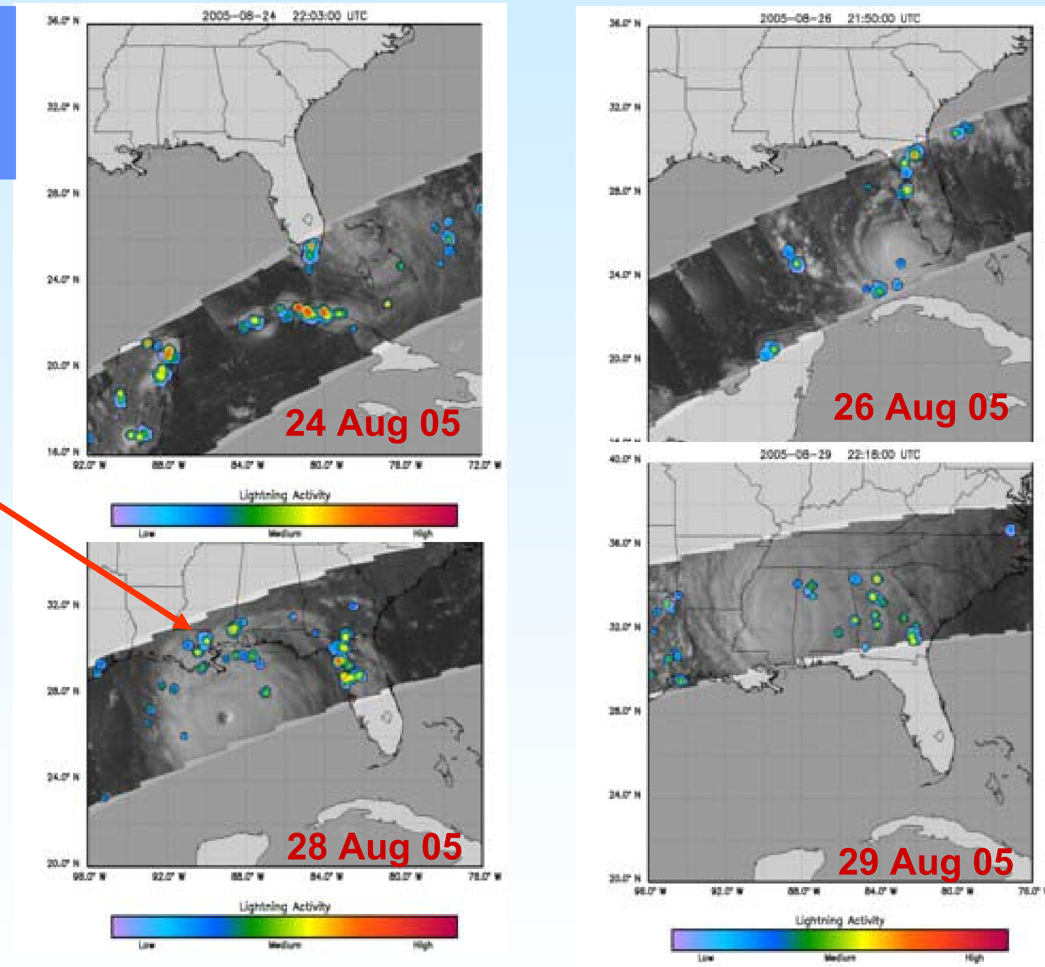


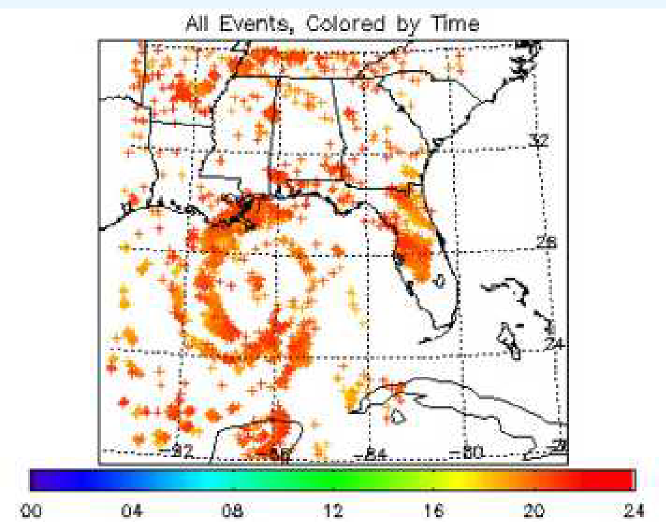
1-min total lightning activity

Hurricane Katrina: Lightning Imaging Sensor (LIS)

How does lightning activity vary as TC/Hurricane undergoes intensity change? Is there a useful predictor?

<u>LIS Background Images</u>
read out once per min
4 km ifov @ 777.4 nm
Orbit swath 600 km

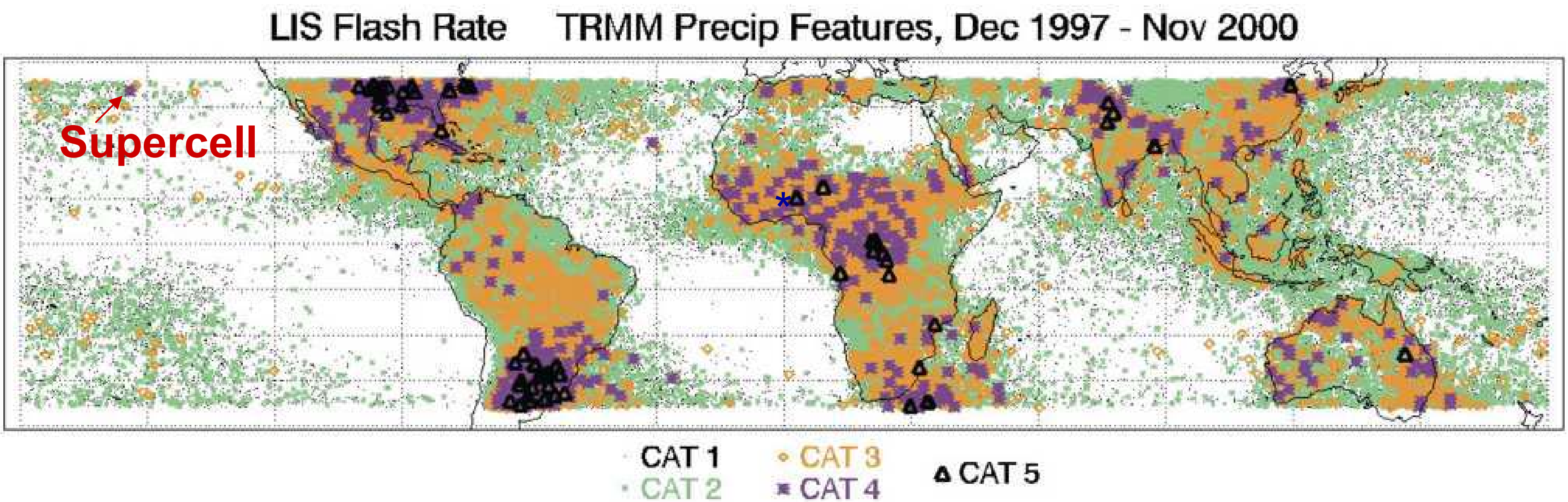




Los Alamos Sferics Array, August 28, 2005, Shao et al., EOS Trans., 86

Most Intense Electrical Storms on Earth

Extreme Lightning Rate Storms
Observed by TRMM LIS
(Cecil et al., MWR, 2005)

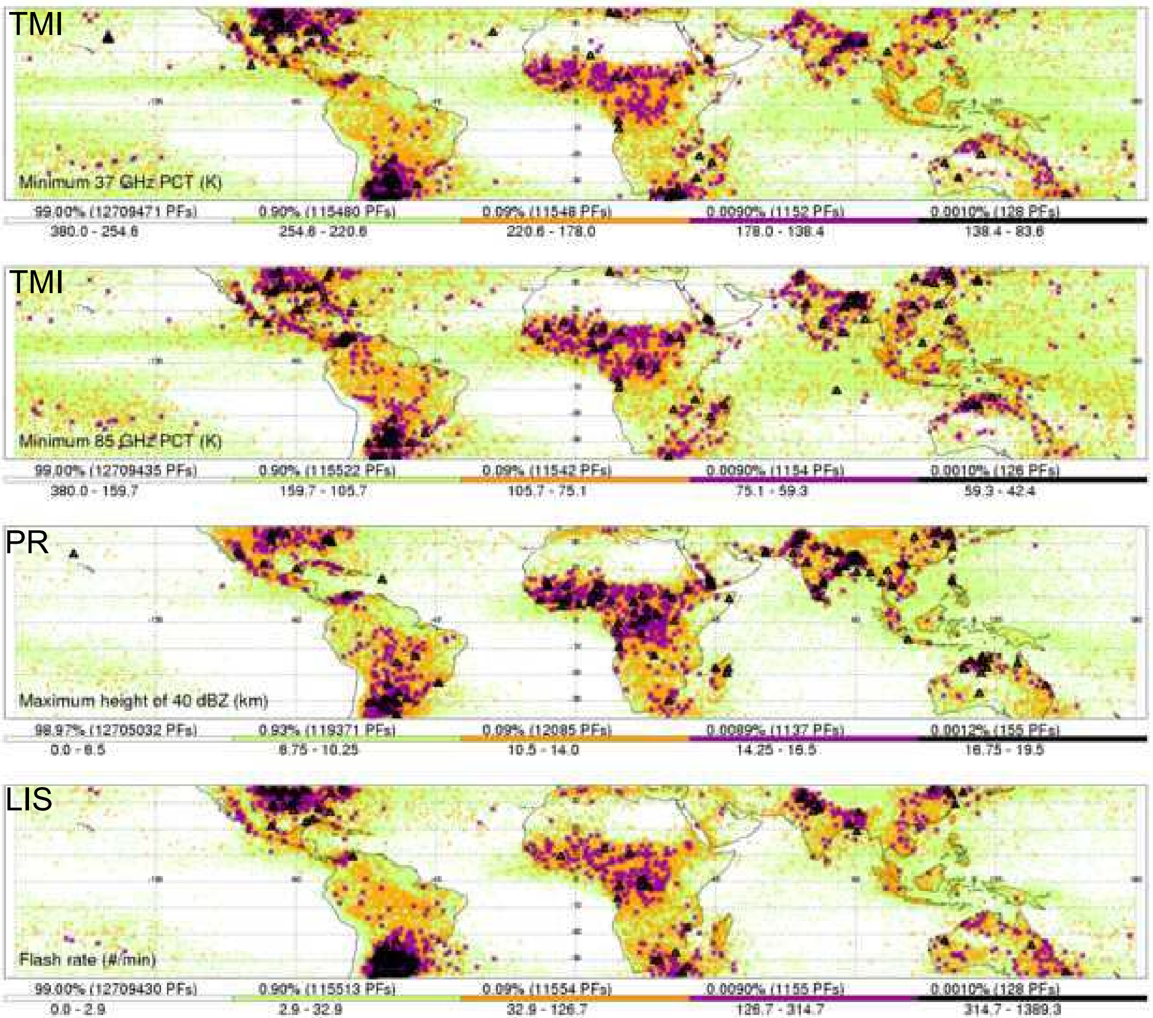


Annual number of casualties due to lightning

- US ~ 1000/yr
- Deaths ~ 80-100/yr
- *Worldwide ~ 25,000/yr? (Holle, 2004)

Where are the Most Intense Thunderstorms on Earth?

(E. J. Zipser, Daniel J. Cecil, Chuntao Liu, Stephen W. Nesbitt and David P. Yorty.
Bulletin of the American Meteorological Society, August 2006



-Most intense convective storms on earth; color code indicating their rarity.

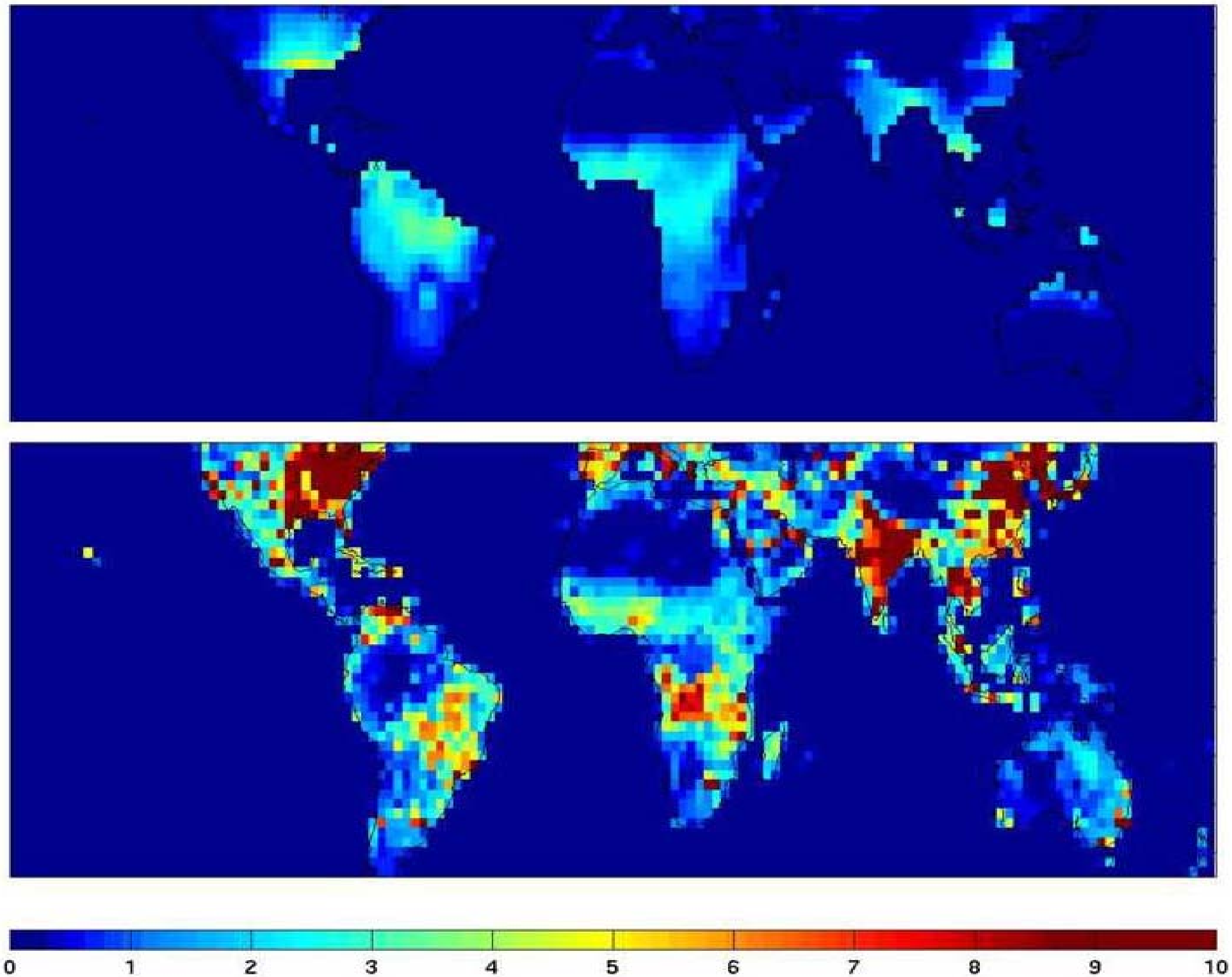
-The deepest and most electrically active storms, indicated by the black triangles, also have large amounts of precipitation-sized ice and hail, as indicated by the very cold microwave brightness temperatures.

-A line of storms in northern Argentina produced more than 1000 discharges per minute, the greatest flash rate observed to date.

-During the eight year period 1998-2005 nearly 13 million storms have been observed by the suite of instruments on the Tropical Rainfall Measuring Mission.

Current Estimate of Annual Global NOx Sources

(Martin, R., et al., Space-based constraints on the production of nitric oxide by lightning, JGR, 2007)



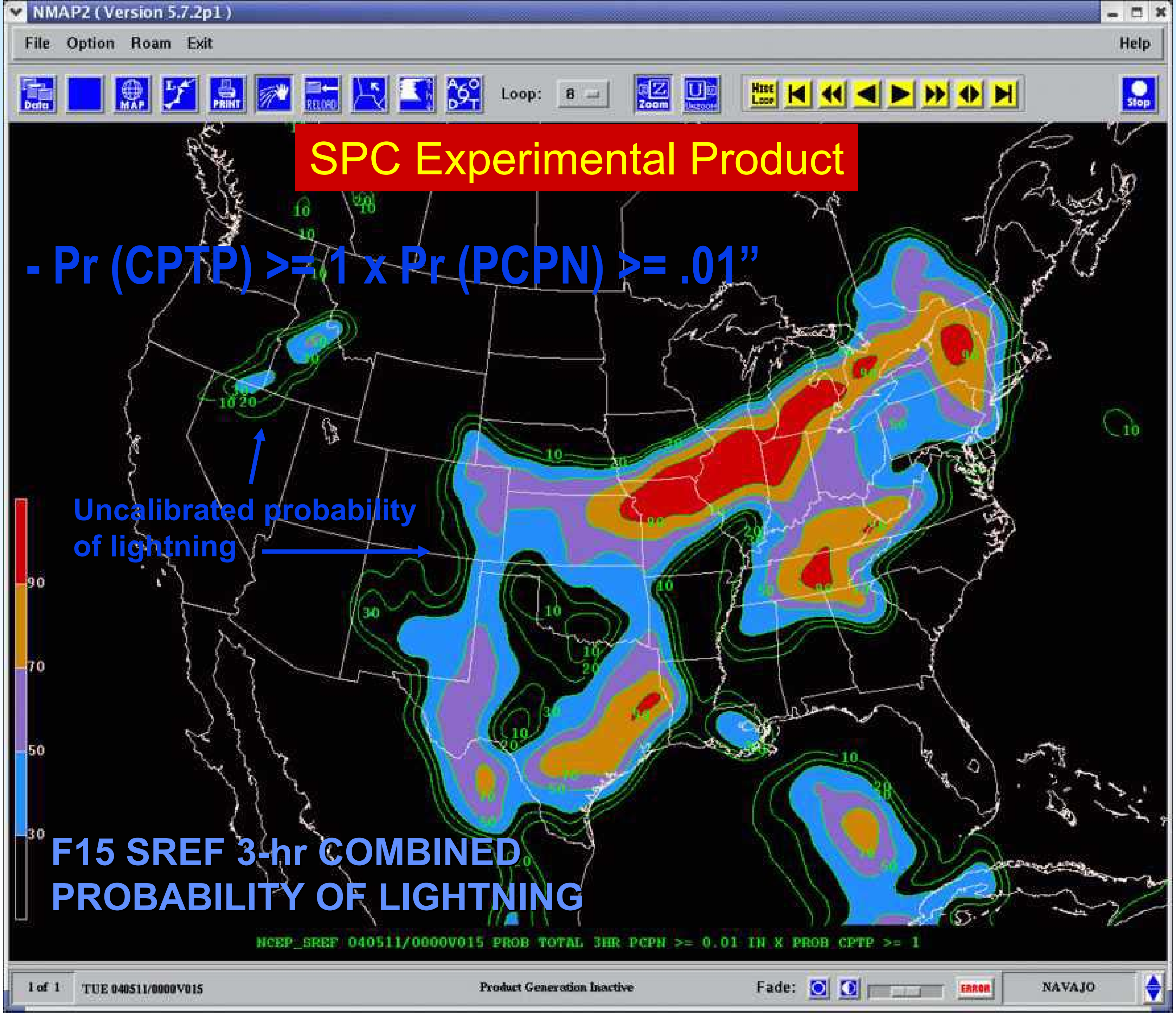
10^{10} molecules N cm^{-2} s^{-1}

Lightning

6 Tg N yr^{-1}

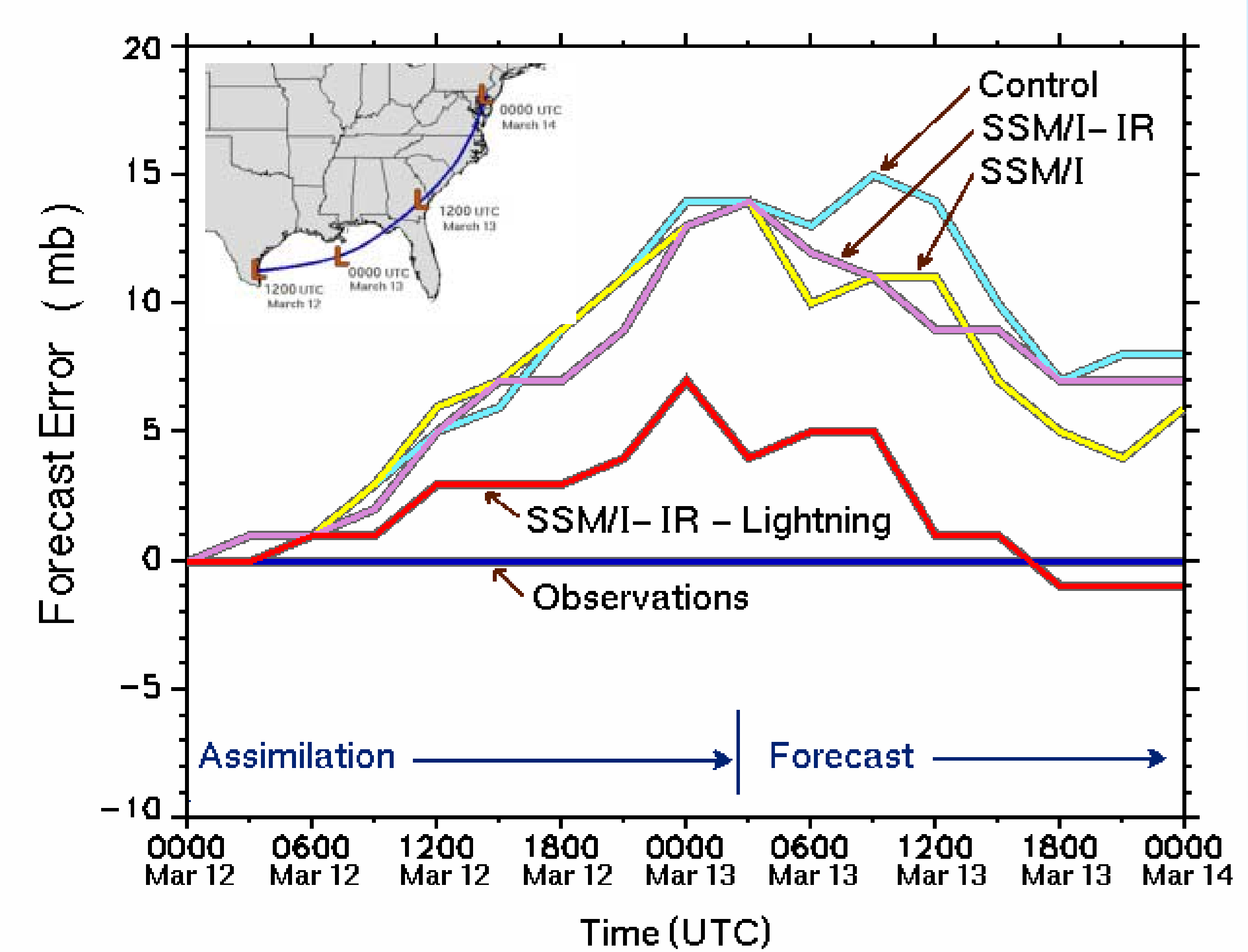
Other NOx sources: (fossil fuel, biofuel, biomass burning, soils)

39 Tg N yr^{-1}


NMAP2 (Version 5.7.2p1)
File Option Roam Exit
Help
Loop: 8
SPC Experimental Product
- Pr (CPTP) >= 1 x Pr (PCPN) >= .01”
Uncalibrated probability of lightning
90
70
50
30
F15 SREF 3-hr COMBINED PROBABILITY OF LIGHTNING
NCEP_SREF 040511/0000V015 PROB TOTAL 3HR PCPN >= 0.01 IN X PROB CPTP >= 1
1 of 1
TUE 040511/0000V015
Product Generation Inactive
Fade:
NAVAJO

Lightning Data Assimilation: Reduces Forecast Error

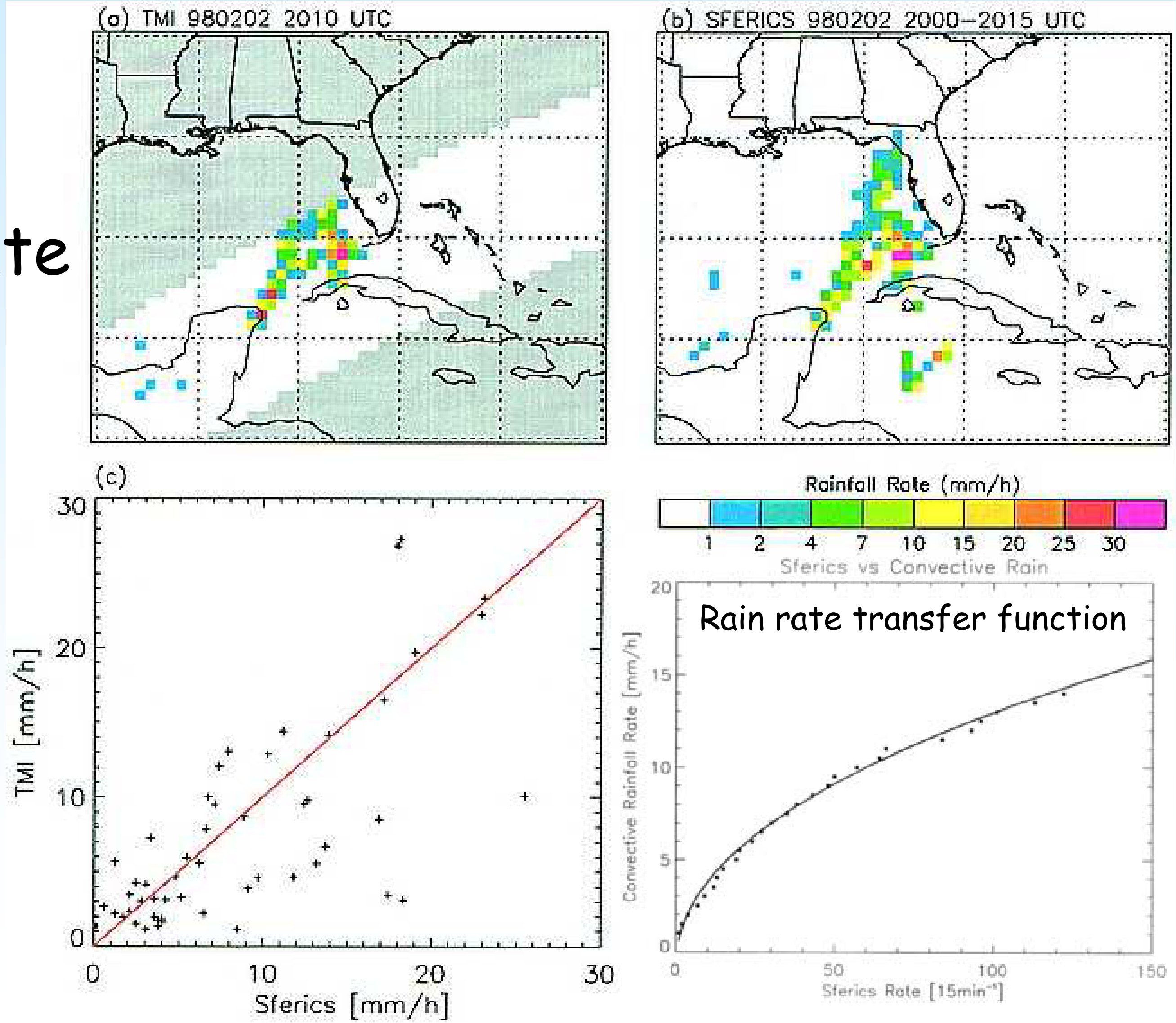
March 13, 1993 Superstorm (Alexander et al., 1999 MWR)



Lightning Data Assimilation: From Flash Rate to Latent Heat

Establish a Lightning – Rain Rate Transfer Function

TMI GPROF Rain Rate



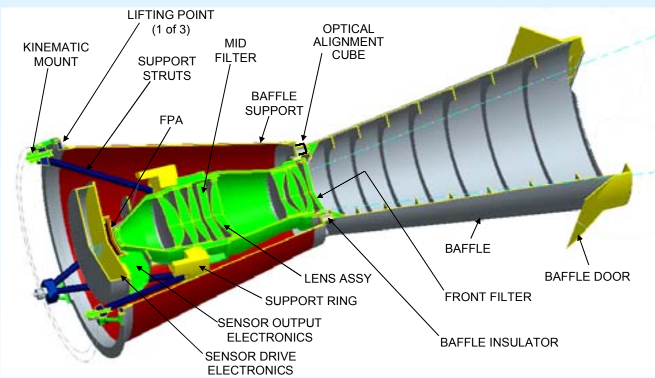
Sferics Rain Rate

Integrated System Performance Exceeds Requirements

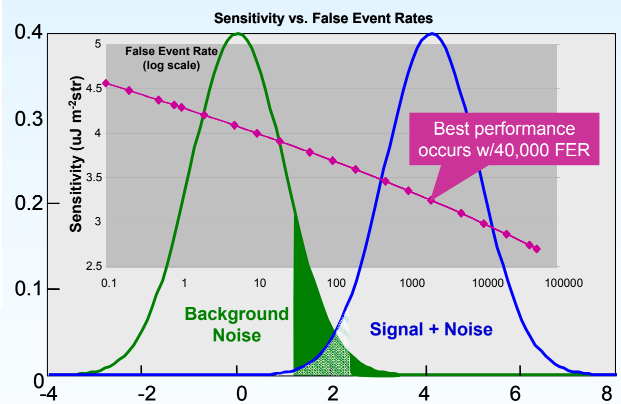
GOES-R GLM Mission Objectives

Provide continuous **Full-Disk** lightning measurements	Provide longer warnings of tornadic activity			Accumulate decadal lightning data
	False Alarm Probability <5%	Detection Probability >70%	Track lightning flash to storm cell; Calculate optical center over time	

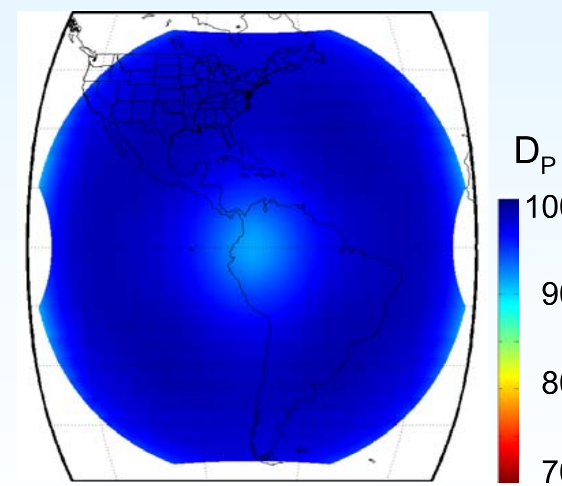
FOV = full-disk [16°]
GSD = 8 km at nadir
1372 x 1300 pixel CCD



False Alarm Probability <5% [<3%]



Detection Probability >70% [>90%]



Black text = requirement
[Blue text] = capability

Robust performance through EOL with high sensitivity and detection probability results in longer warning of tornadic activity

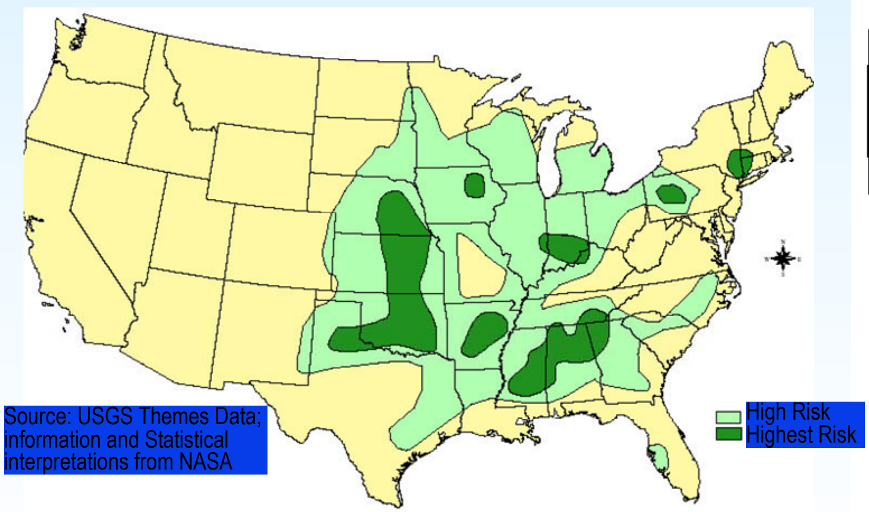
Courtesy LMATC

Analysis and Test Cases Predict Good Performance Margins

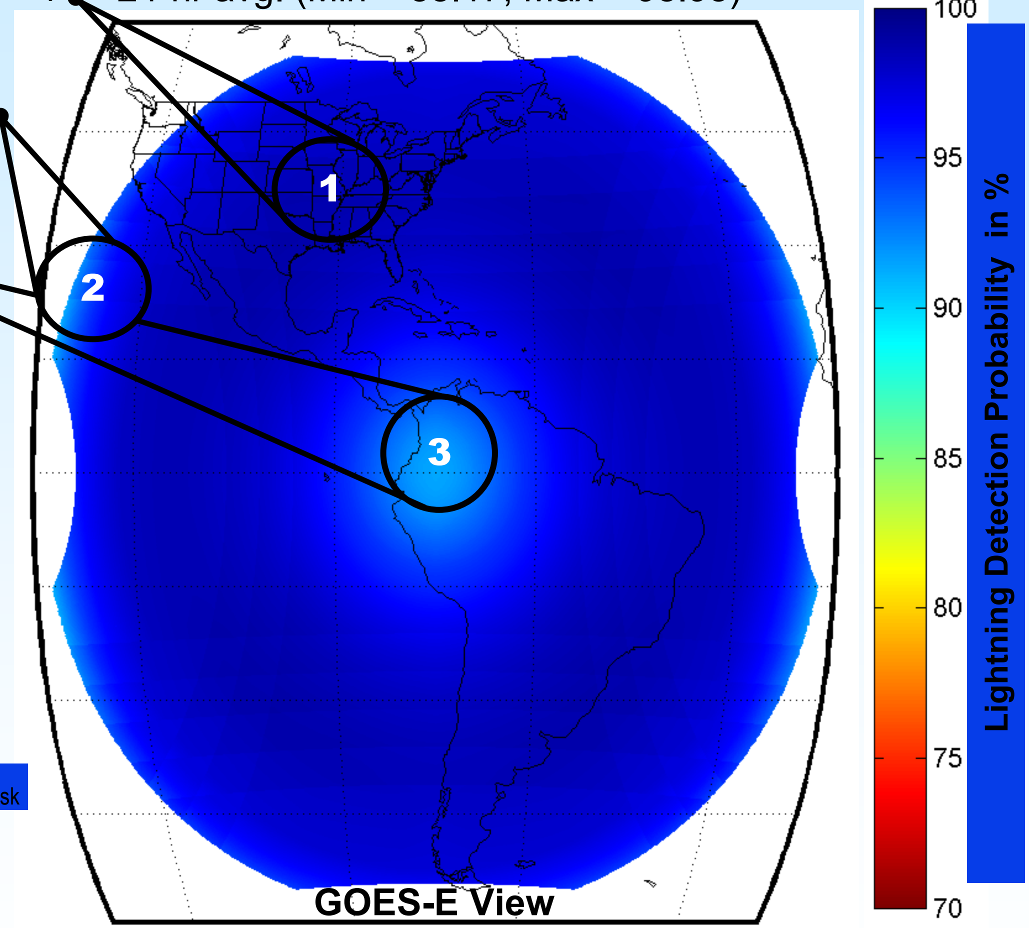
Case 1 [Capability]: **Tornado alley** (5.5°)
Ab = 8 km × 8.5 km [6.8E7 km^2]

Case 2 [Baseline]: Edge of FOV (8°)
Ab = 12 km × 8 km [9.6E7 km^2]

Case 3 [Baseline]: Nadir (0°)
Ab = 8 km × 8 km [6.4E7 km^2]



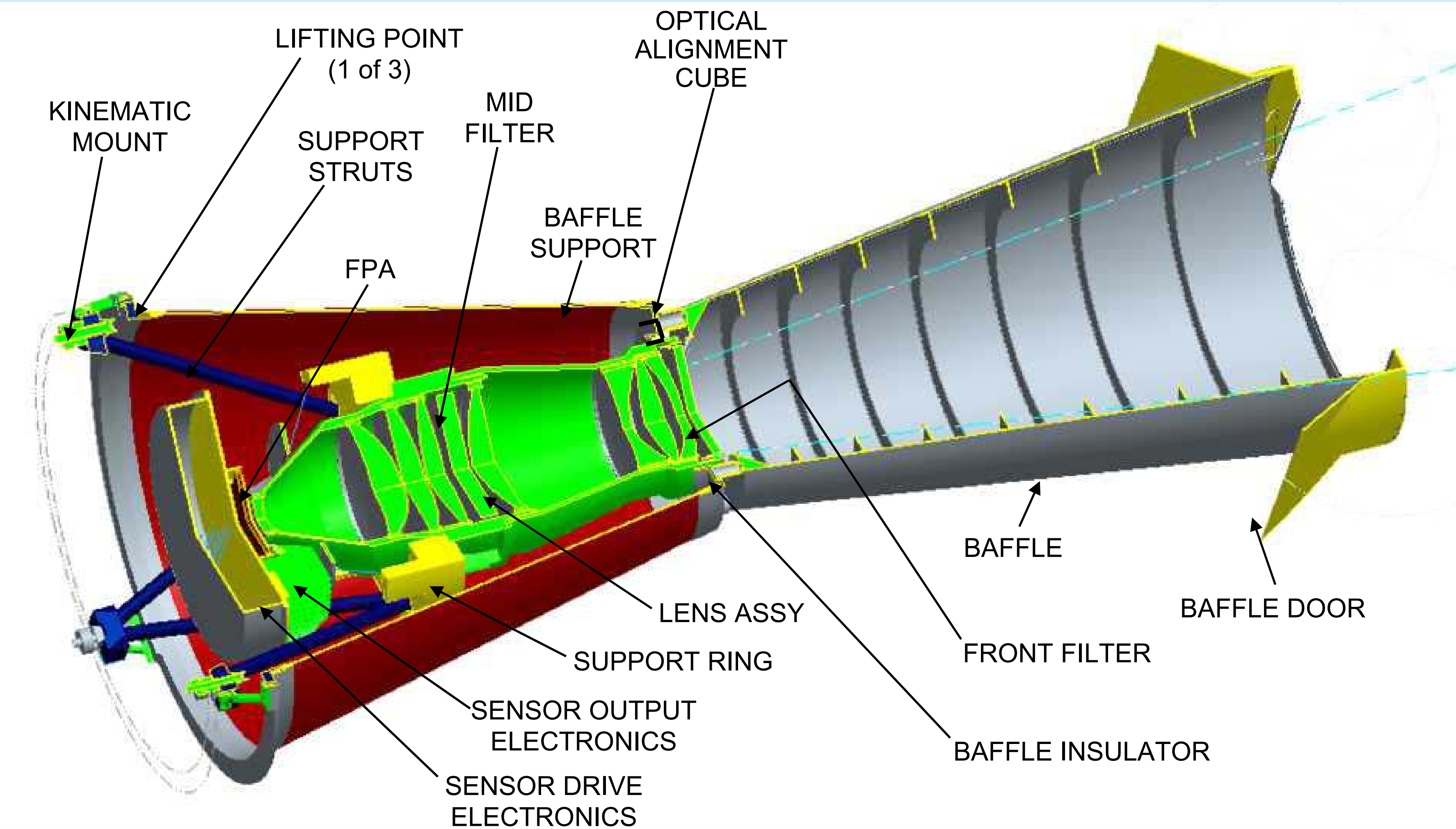
Predicted Detection Probability
24-hr avg. (Min = 88.17; Max = 98.98)



GLM provides detection performance margin in worst-case, daylight conditions and over full-disk, critical geographical areas (Tornado Alley)

Courtesy LMATC

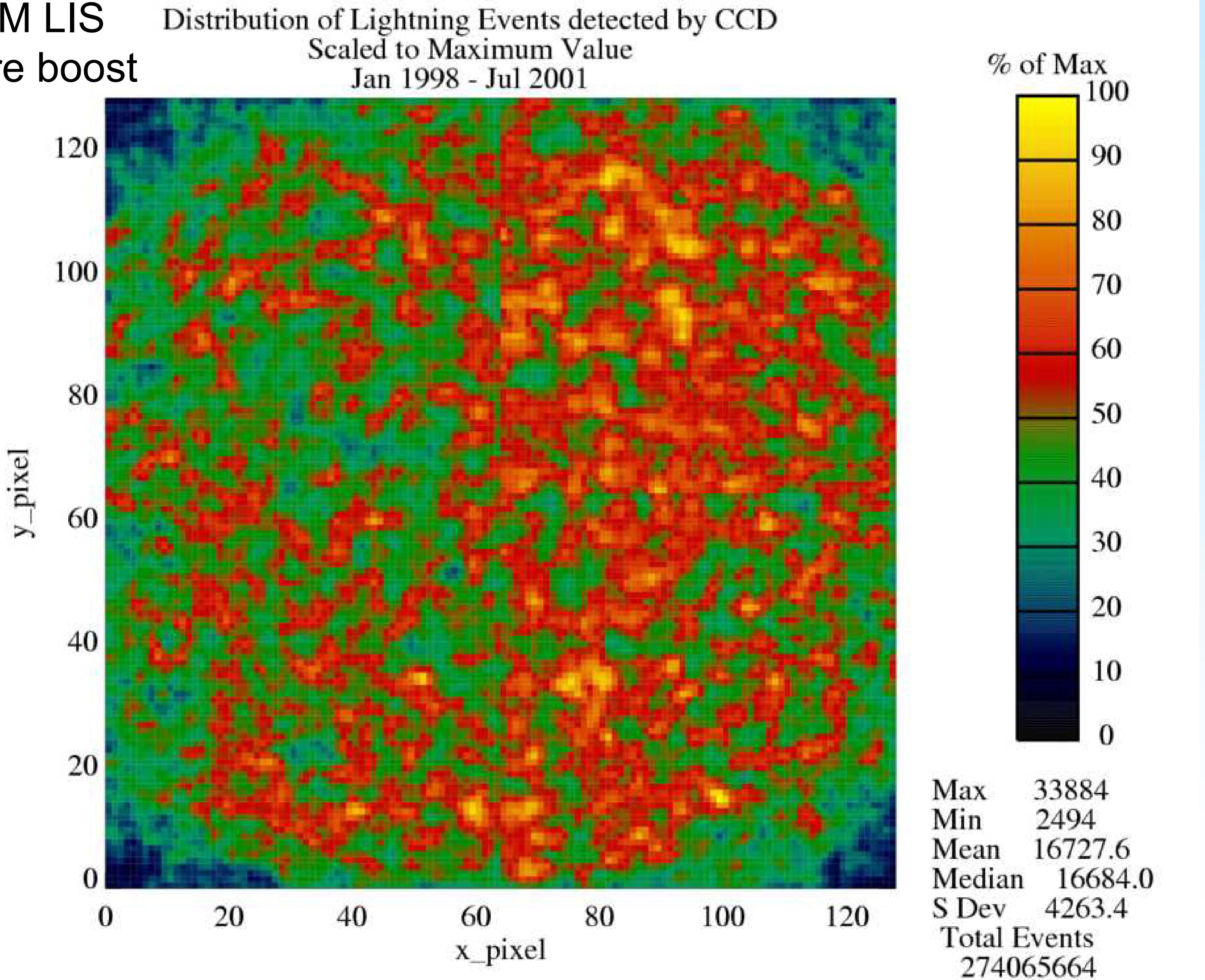
GLM Sensor Unit (SU)



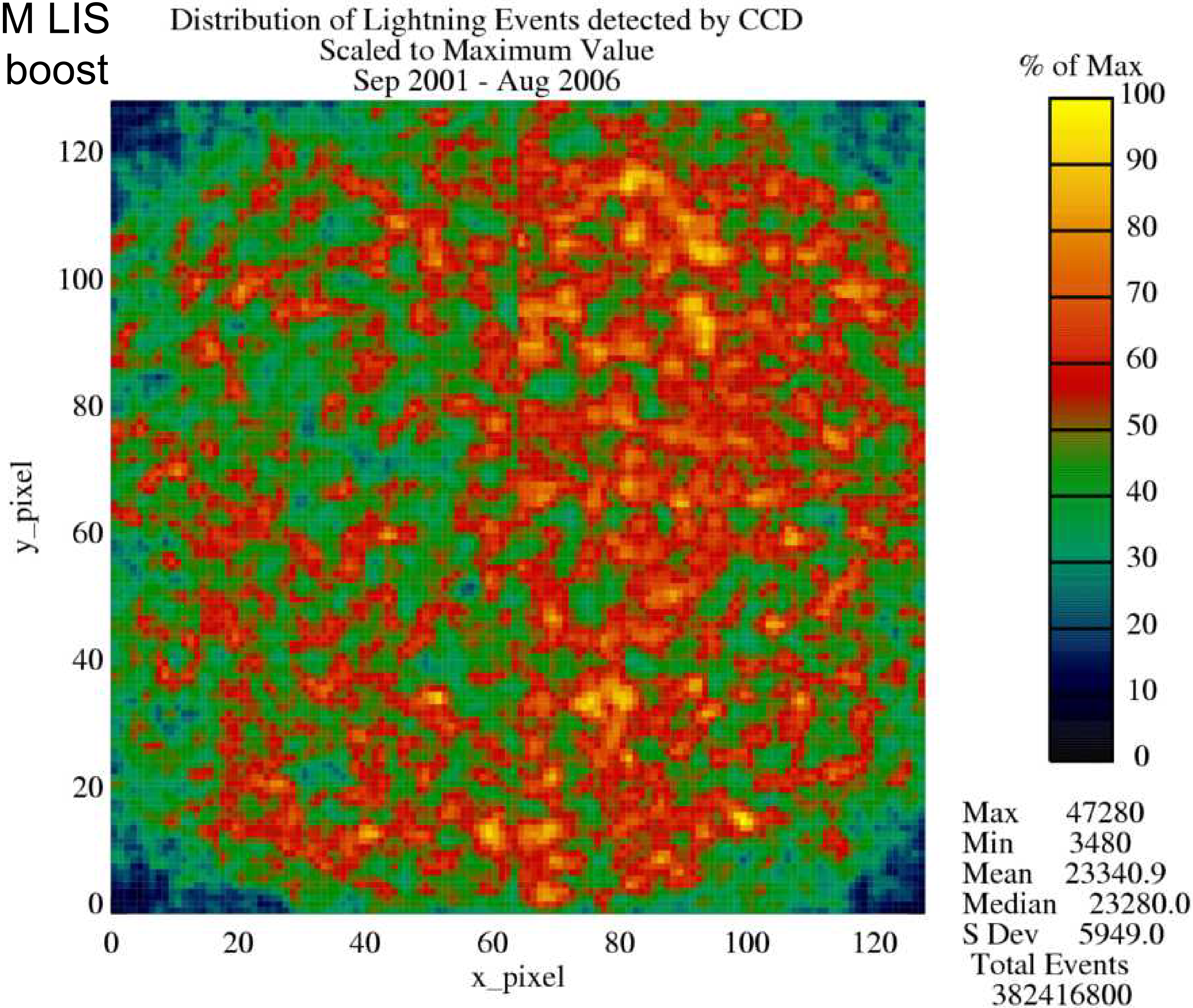
The Sensor Unit combines a well-baffled refracting telescope with a CCD focal plane array, including multi-channel CCD drive and output electronics.

Courtesy LMATC

TRMM LIS
before boost



TRMM LIS after boost



Ground Processing Algorithms

On-Orbit Data Acquisition

1. Background scene tracking & removal
2. Thresholding
3. Event detection

- Background scene acquired
- Background tracking algorithm updates background
  - Response time constant fast enough to track changes caused by S/C motion component
  - Background subtracted from signal pixel by pixel
- Thresholding (events exceeding background are transmitted to ground)
  - Amplitude algorithm processes only larger events
  - Reduces # of processed events so data is compatible with telemetry bandwidth
- Event detected

Level 1/1b Processing

Filter false events

2nd Level Threshold Algorithm (1)

- For cases when there are high event rates – used for rapid removal of false events
- Look-up table

Radiation Algorithm (2)

- Removes false events produced by high energy particle collisions

Shot-noise (coherency) Algorithm (3)

- Removes false events produced by noise (S/C, etc)

Contrast Algorithm (4)

- Removes false events produced by S/C motion

Geolocation

Solar glint Algorithm (5)

- Removes false events produced by solar glint
- Performed after geolocation to minimize processing (only regions within potential glint regions)

Time-tag UTC Conversion

Apply pre-launch calibration factors Convert to radiances

Note: Event to group to flash conversion is processed at Level 2

Layered approach to false event removal results in high system performance

Courtesy LMATC

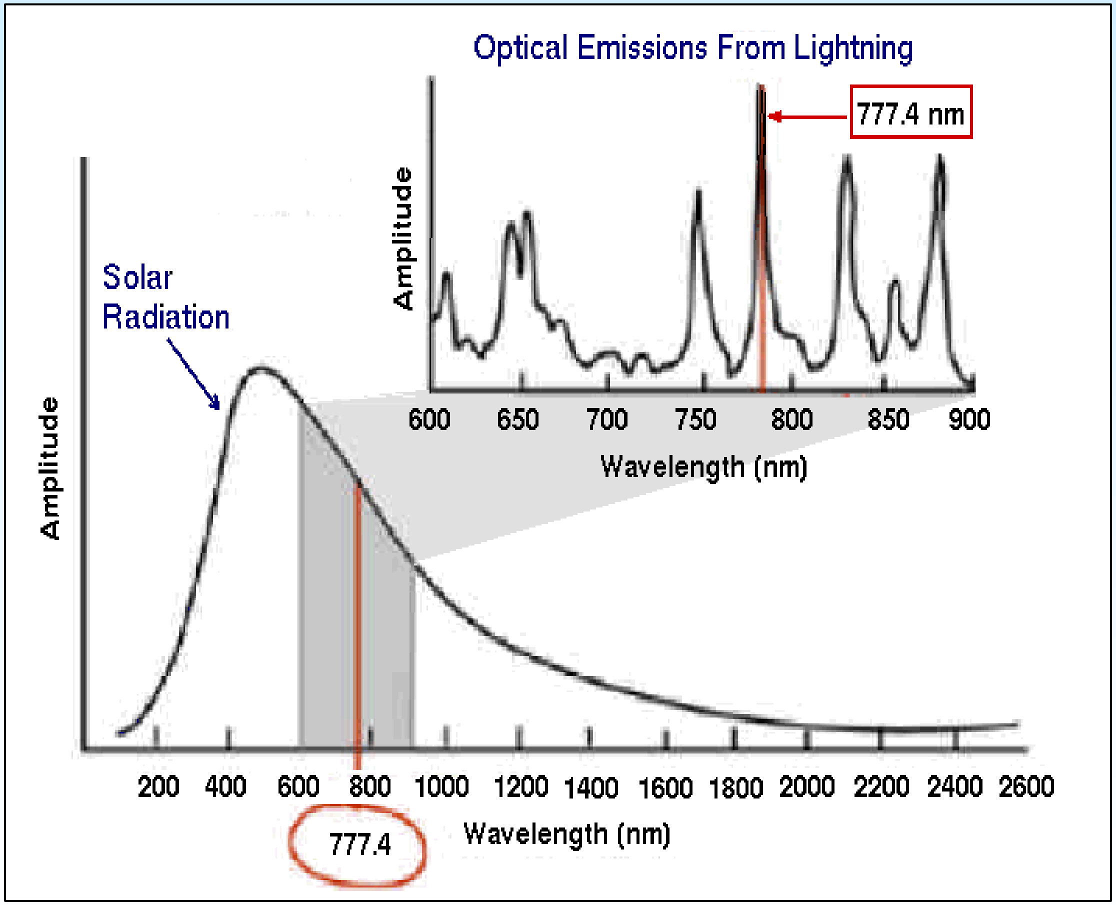
Instrument Implementation
Measurement Approach

Key problem that OTD/LIS/GLM solves is the detection of dim lightning against a much brighter background during the day.

Four techniques utilized:

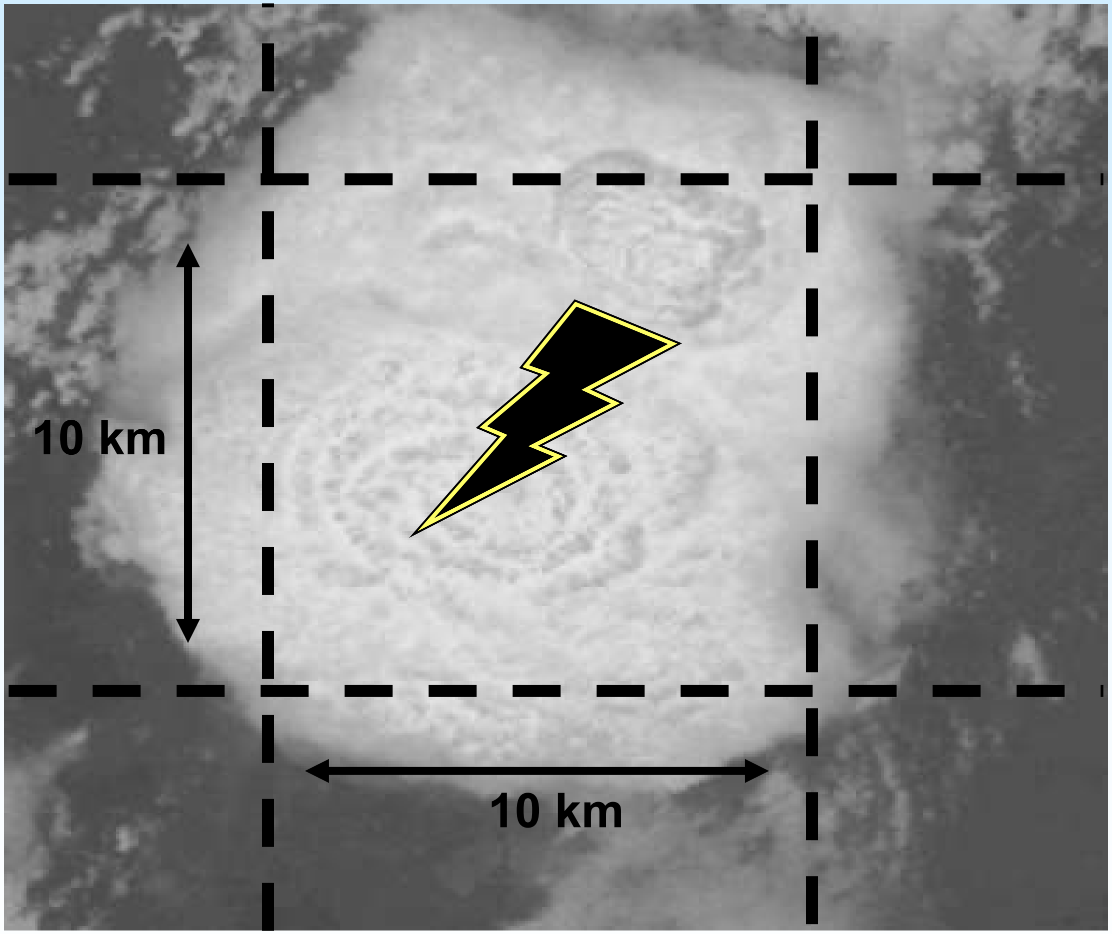
1. Spectral filtering
2. Spatial discrimination
3. Temporal discrimination
4. Background Subtraction & Event Detection

Measurement: Spectral Filtering



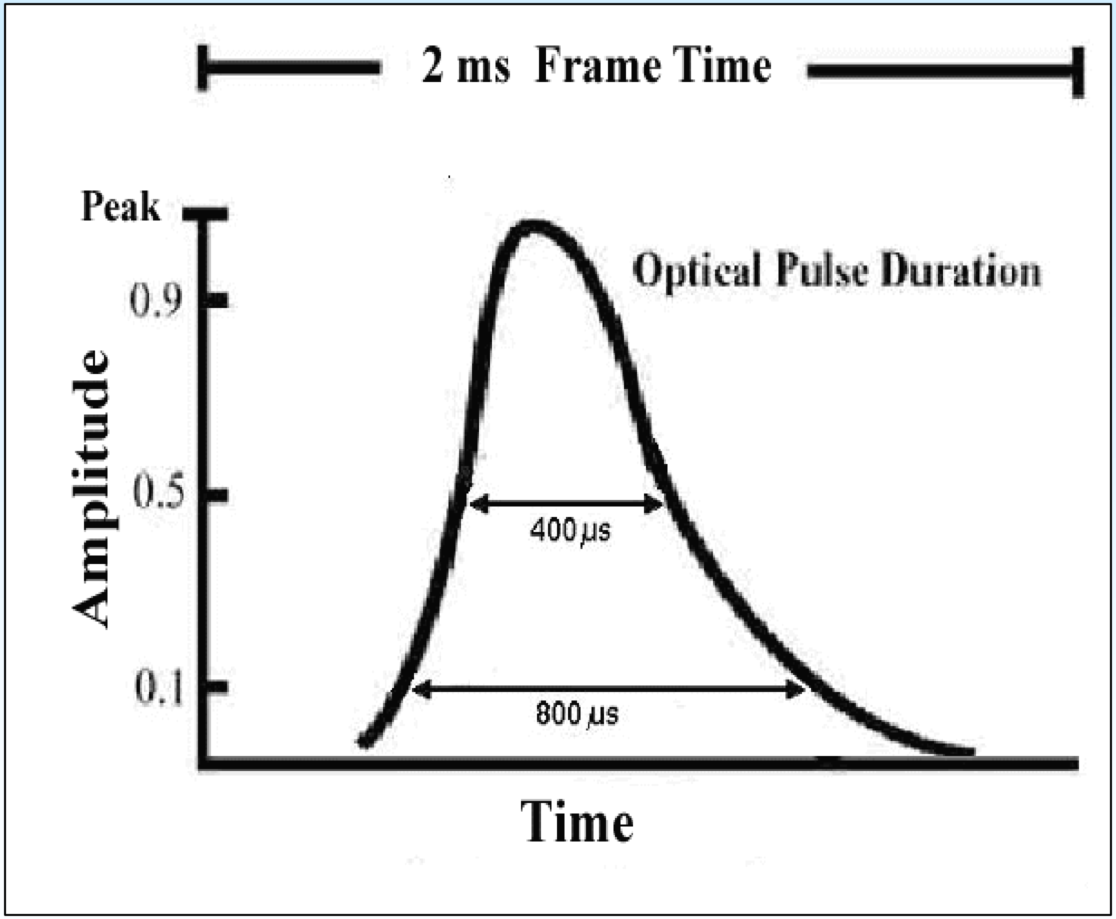
Narrow band interference filter passes only light from 1nm wide oxygen multiplet

Measurement: Spatial Discrimination



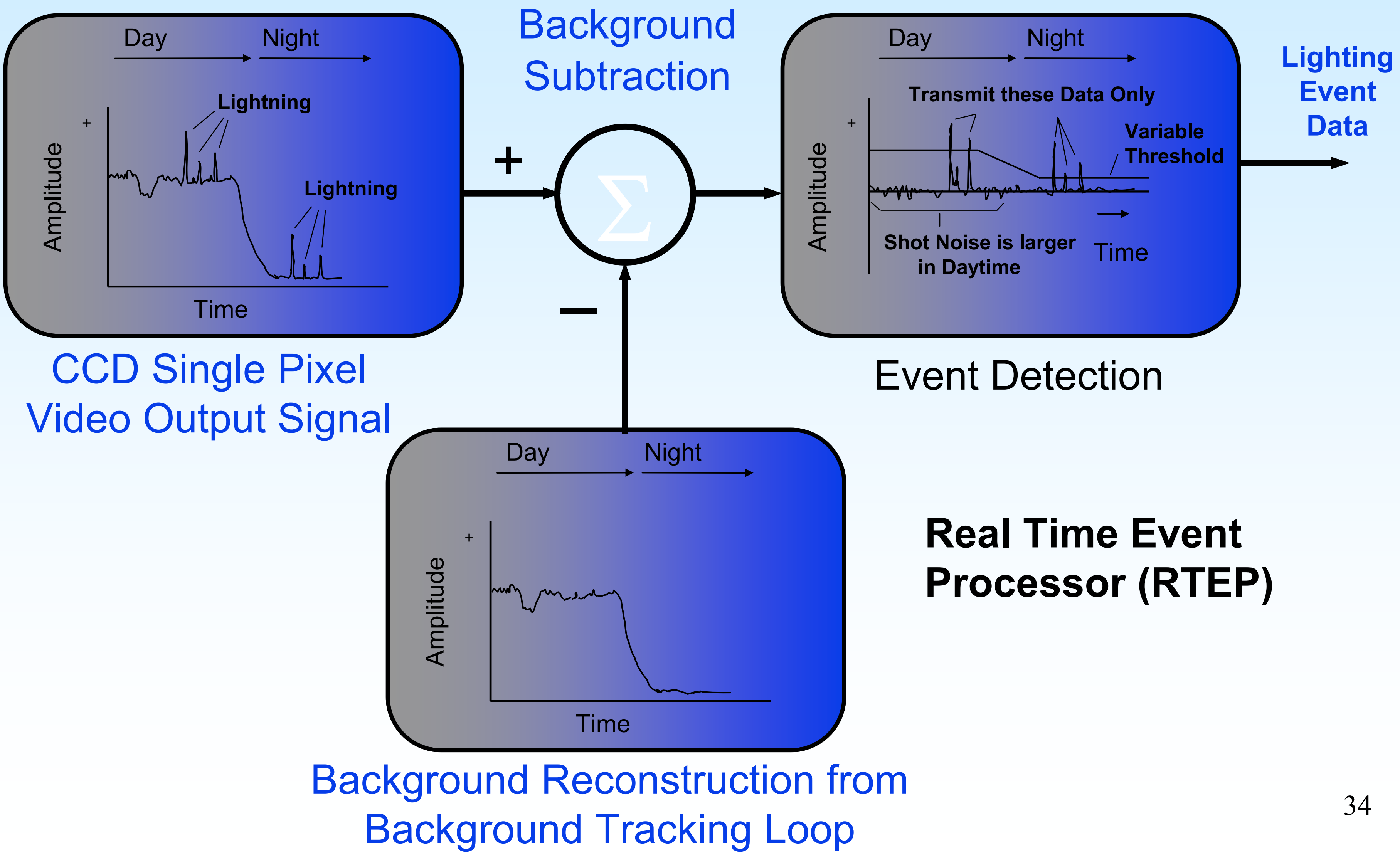
10km nominal spatial resolution optimizes the lightning-to-background S/N ratio.

Measurement: Temporal Discrimination



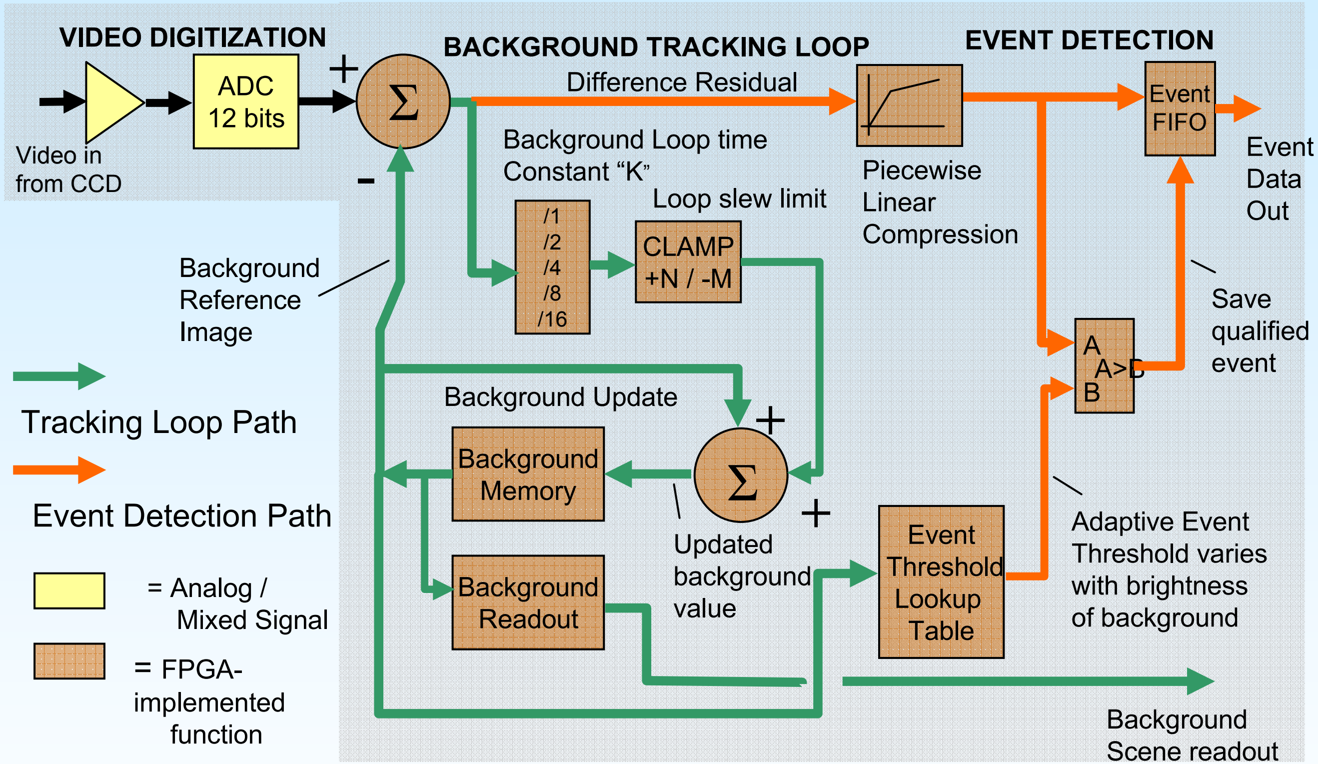
CCD integration interval is set to 2 ms to minimize pulse splitting between frames and minimize integration of background signal

Measurement:
Background Subtraction & Event Detection



RTEP Block Diagram

Working Electronics Unit breadboard with 4 RTEPs coupled to a Data Formatter exceeds GLM requirements

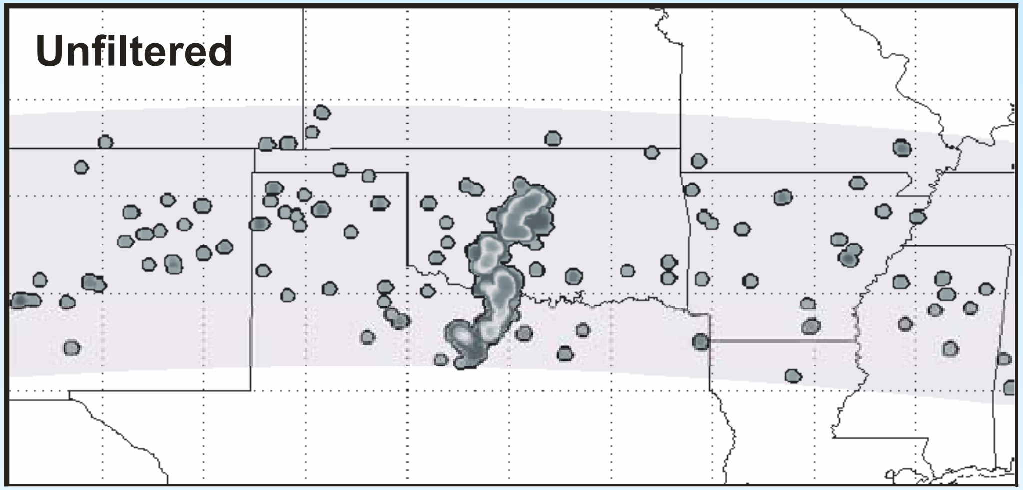


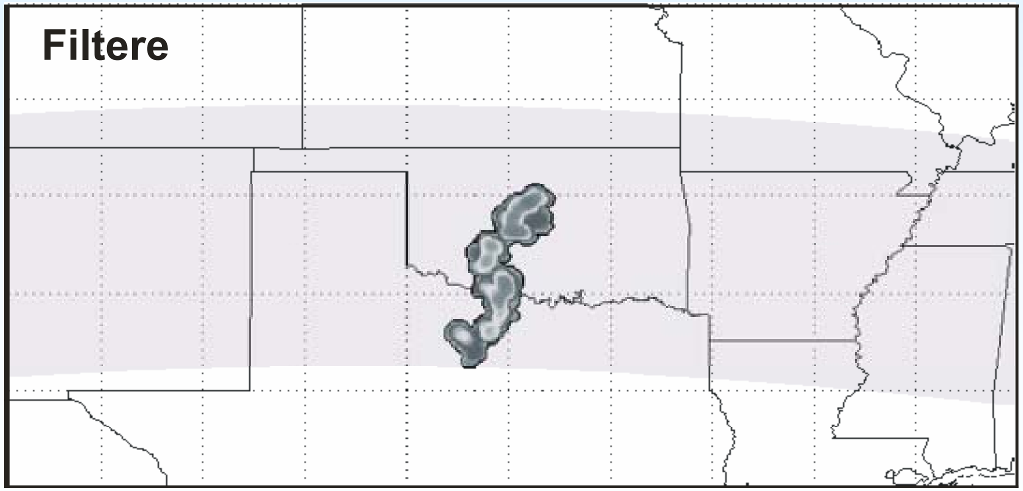
Real Time Event Processor (RTEP) provides on-board event detection.

Courtesy LMATC

False Alarm Removal

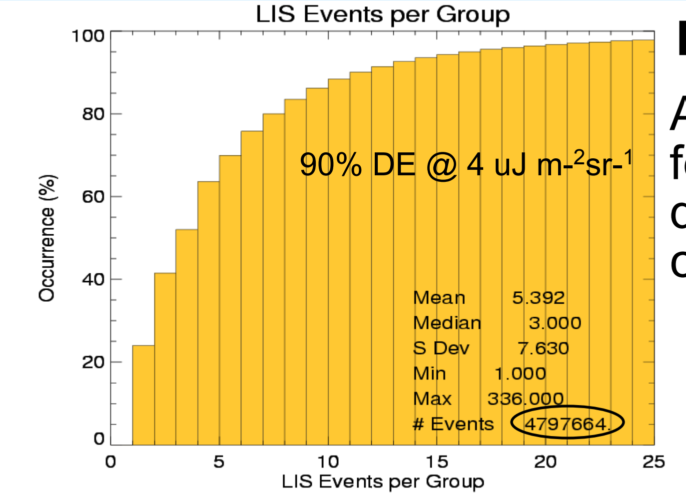
- False events (FE) are removed on the ground during level 1b processing
- Unfiltered data show many false lightning events
  - Many due to radiation
  - These events cannot be removed by amplitude thresholding alone - some are quite intense
- After filtering, lightning-only data shows coherency
- High system sensitivity maximizes the number of detected optical lightning pulses
- Use of coherency minimizes mistaking false events as lightning





Experience with LIS data provides insight and methodology for efficient GLM false event removal

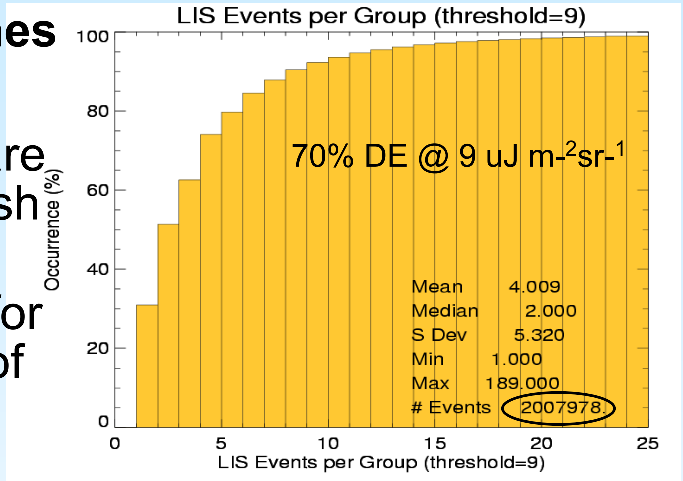
Coherency Filter - Requires Multiple Detections During a Flash

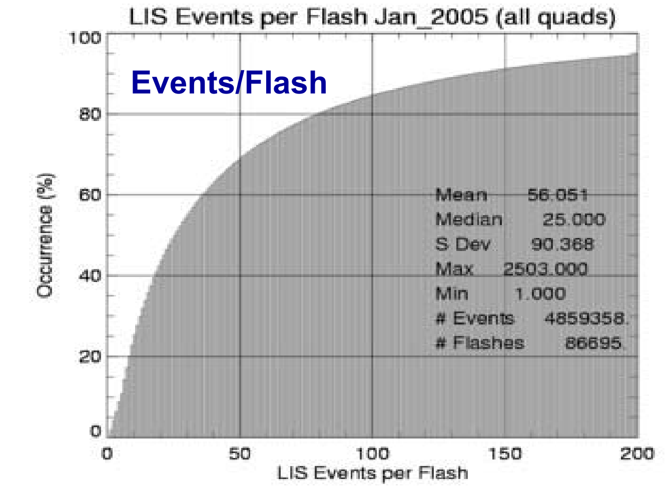


Events ➞ Groups ➞ Flashes

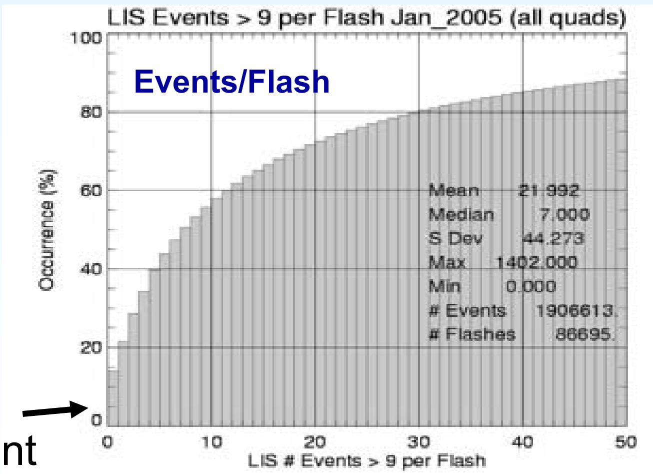
As sensitivity decreases, fewer events and groups are detected, making intra- flash coherency less effective

- As shown on the right, for a low DE sensor, 15% of the flashes consist of a single event
- In this case DE is effectively reduced by > 20% if coherency is required
- If coherency is not used, strong false events are labeled lightning





15 % of flashes have only 1 event



The majority of lightning pulses (most of which are very weak) are collected and available to level 1b algorithms

Courtesy LMATC

GLM Risk Reduction

- **Analysis of proxy data from TRMM LIS and VHF Lightning Mapping Arrays**
- **Test beds to collect comprehensive data on storms to advance the science**
- **Forecaster assessments of total lightning data in the Warning Decision-Making Process**

Algorithm Development Strategy

Candidate Algorithms

Testing and Validation

- *Proxy and Simulated Data*
- *Algorithm Selection*
- *Demonstrating Algorithm Performance*

Candidate Algorithms

- **Clustering Algorithm**
  - » Description: takes events and creates groups and flashes
    - Pros: TRMM LIS and OTD heritage
    - Cons: non yet extended/optimal for GEO
- **Cell Tracking Algorithm**
    - Pros: LISDAD and RDT heritage, SCIT has limitations
    - Cons: technically challenging, needs AWIPS implementation for optimal utility
- **Flash Trending "Jump" Algorithm**
  - » Description: trends flash rates with time for individual storms
    - Pros: Prototype in development and promising – increase lead time
    - Cons: Requires additional research, needs AWIPS implementation for optimal utility
- **Other Application Team Uses of GLM**
  - » **Hydology**-Precipitation, **AQ**-NOx/Ozone, **Clouds**-Cloud Type/TRW, Hurricane Intensification, **Aviation**-Turbulence, Convective Initiation, Volcanoes

LISDAD- Lightning Information System Data Acquisition and Display (NASA/MIT LL)
RDT- Rapidly Developing Thunderstorm (EUMETSAT SAF/MeteoFrance)

Methodology

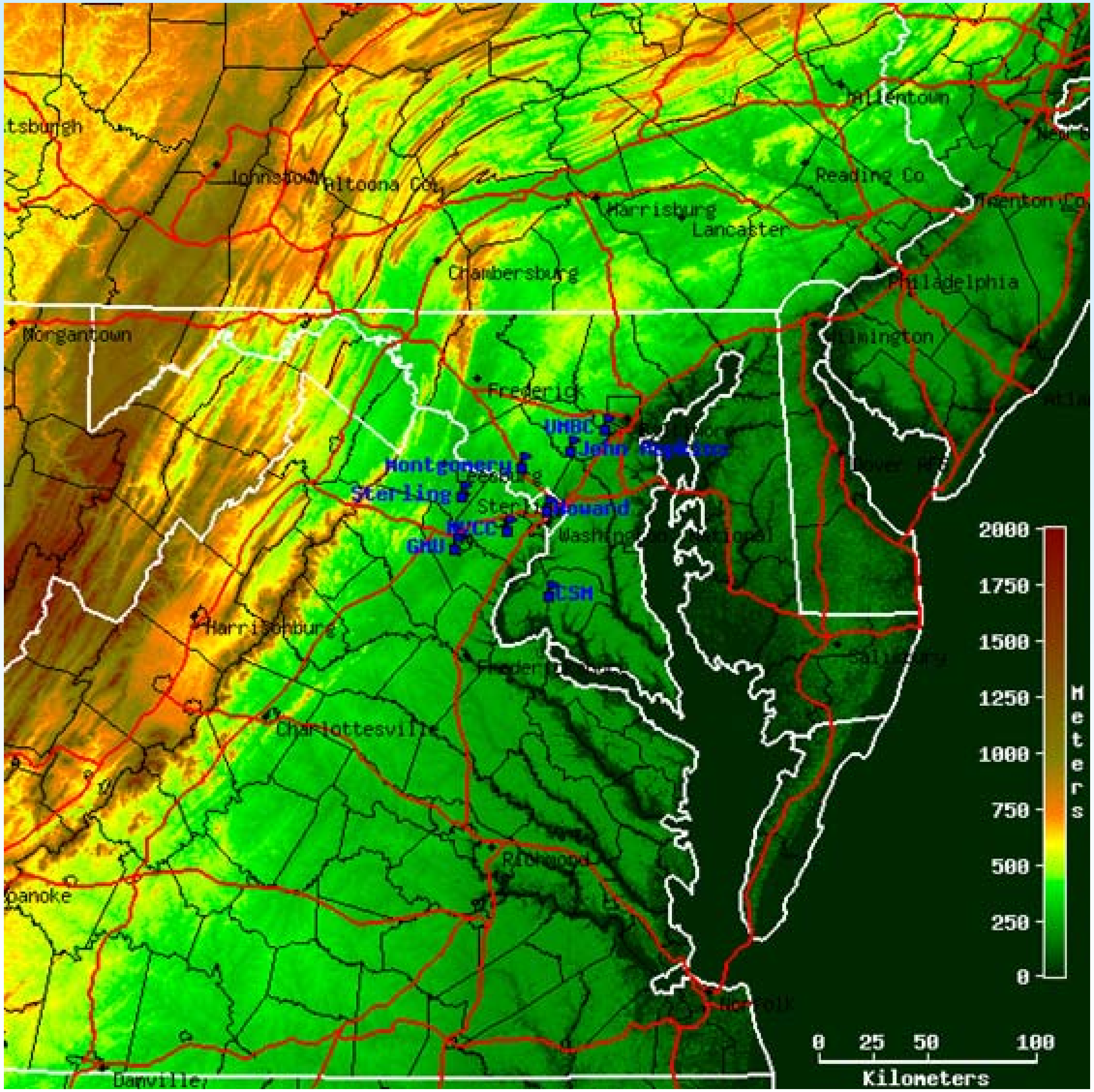
- GLM Proxy Data
  - » Inter-compare LMA channel w/ LIS optical to determine how best to use LMA data as proxy to GLM data.
  - » Applications of LMA data (such as in lightning jump algorithm) will extend to GLM using the proxy data.
  - » Re-sampling of LIS data will also serve as an alternate GLM proxy.
- Exploratory Research (see supplementary charts for items below):
  - » WRF model simulations
  - » Interconnections (Ice-precipitation, updrafts, flash rate)
  - » Flash type discrimination
- Clustering/Filtering
  - » Remove non-lightning events
  - » Approach needs to be consistent/coordinated with GLM instrument contractor responsible for L1B algorithms
  - » Lightning products- events, groups, flashes

Washington, DC Lightning Mapping Array

(in progress- 8 stations as of September 2007)

Channel 10, 192-198 MHz (upper VHF), 8-10 stations

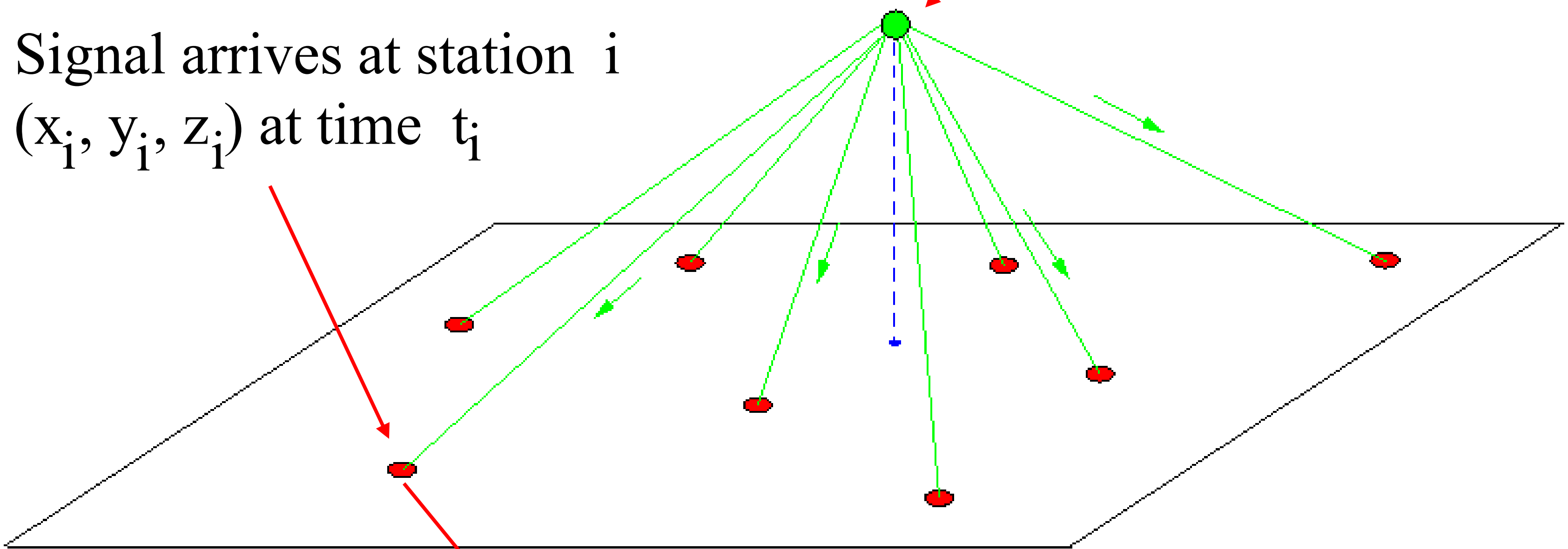
Regional Topography Across LMA Domain



DEM from the Shuttle Radar Topography Mission, (SRTM) finished 3 arc second data, (~90 meters).

Time-of-arrival (TOA) technique

Impulsive lightning event at (x, y, z, t)



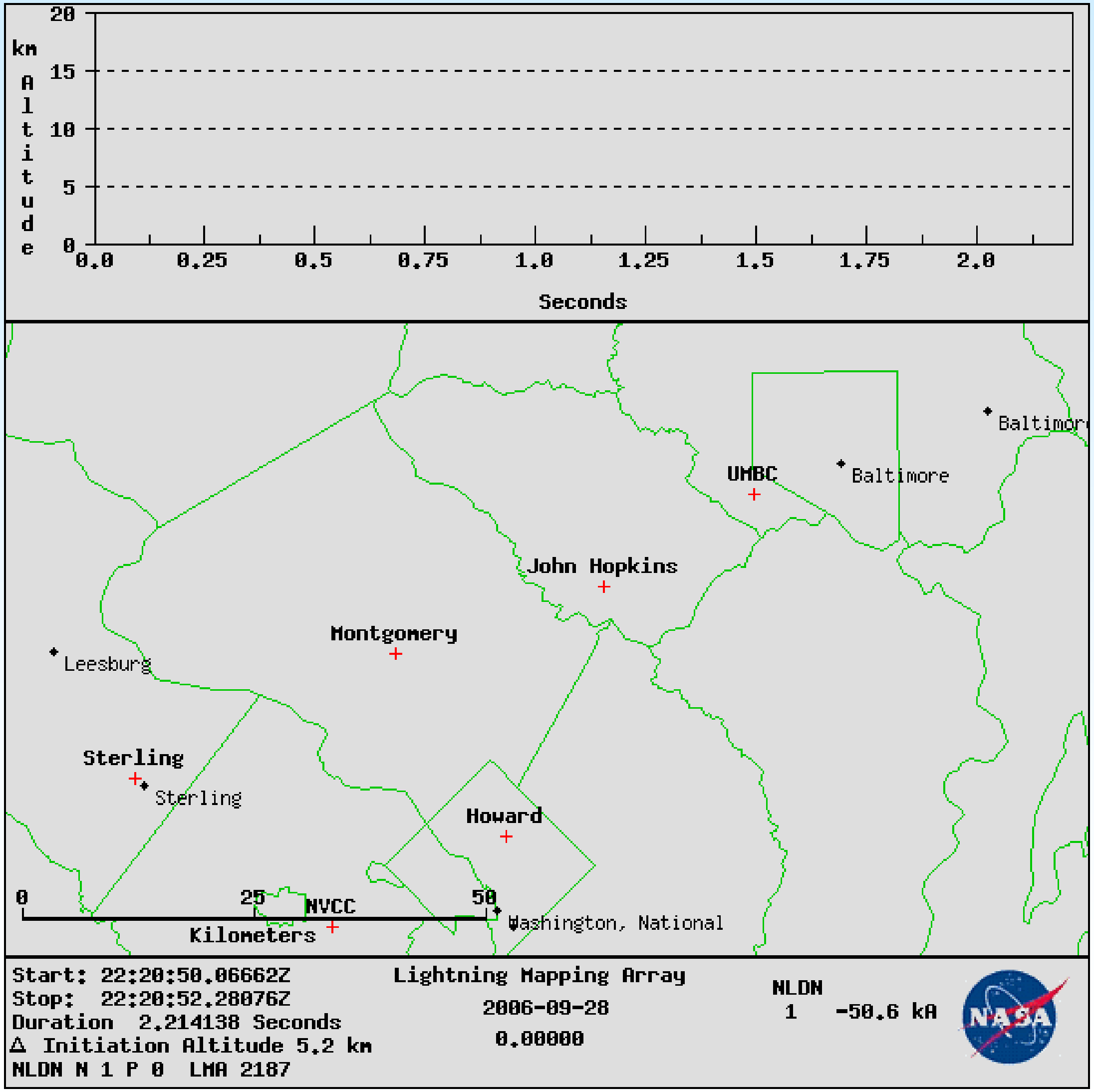
$$t_i = t + \frac{\sqrt{(x_i - x)^2 + (y_i - y)^2 + (z_i - z)^2}}{c}$$

The Lightning Mapping Array measures the time of arrival of RF radiation from a lightning discharge at multiple stations, and locates the sources of the radiation to produce a three-dimensional map of total lightning activity (x, y, z, t).

- Measure t_i at N>4 locations (50 ns accuracy)
- Solve for x, y, z, t (4 unknowns)

DC Area Lightning Discharge- Animation

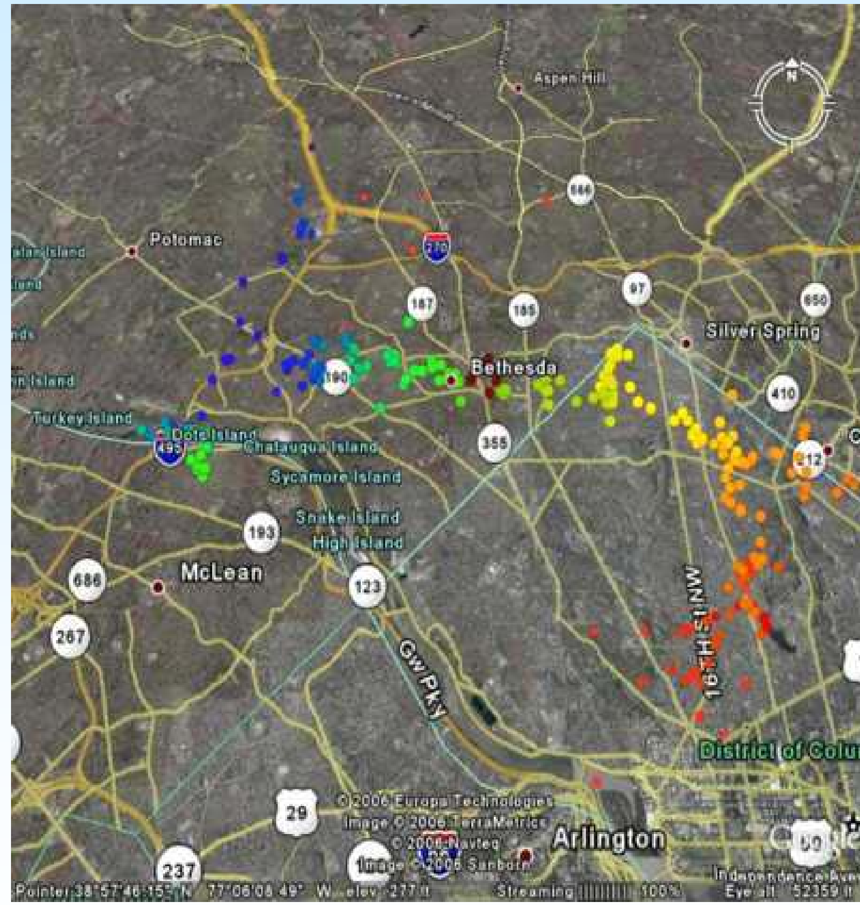
- 2.2 sec hybrid flash
- 50 km horiz extent
- Initiation at 5.2 km
- VHF Sources 2187
- CG strike at 2 s



Animated gif

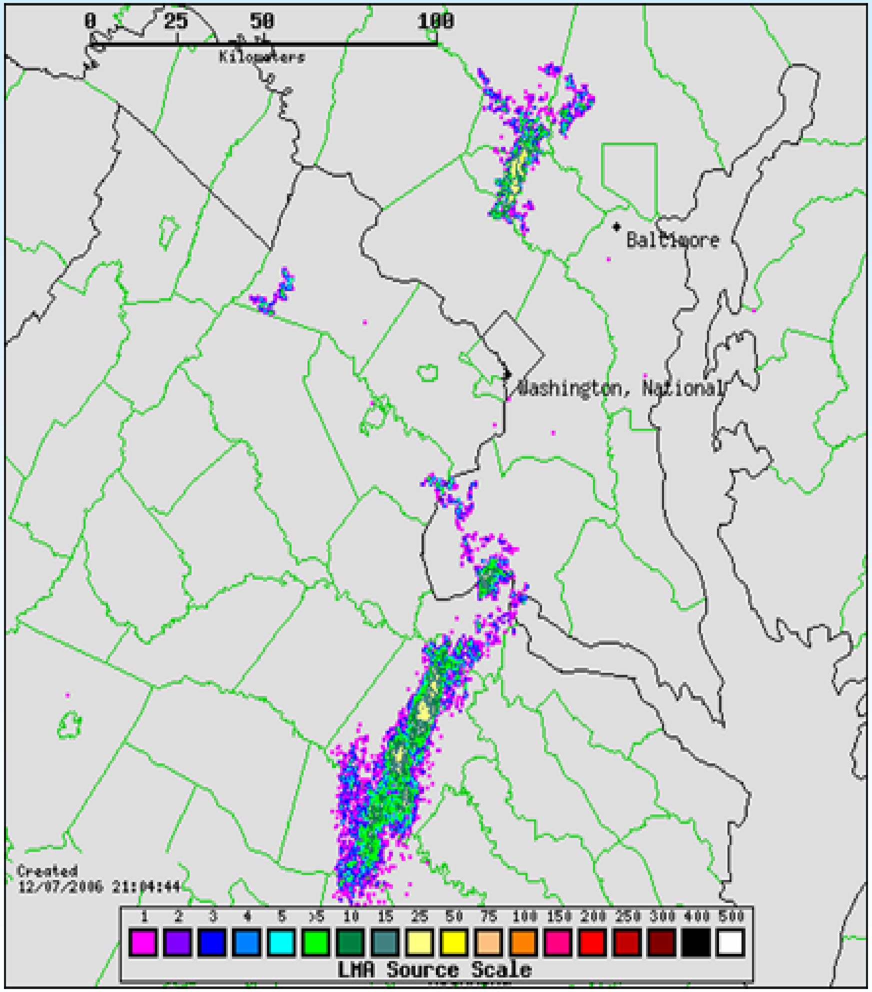
Google Flash 4 August 2006

"Bolt from the Blue" Flash at 00:52:44 UTC

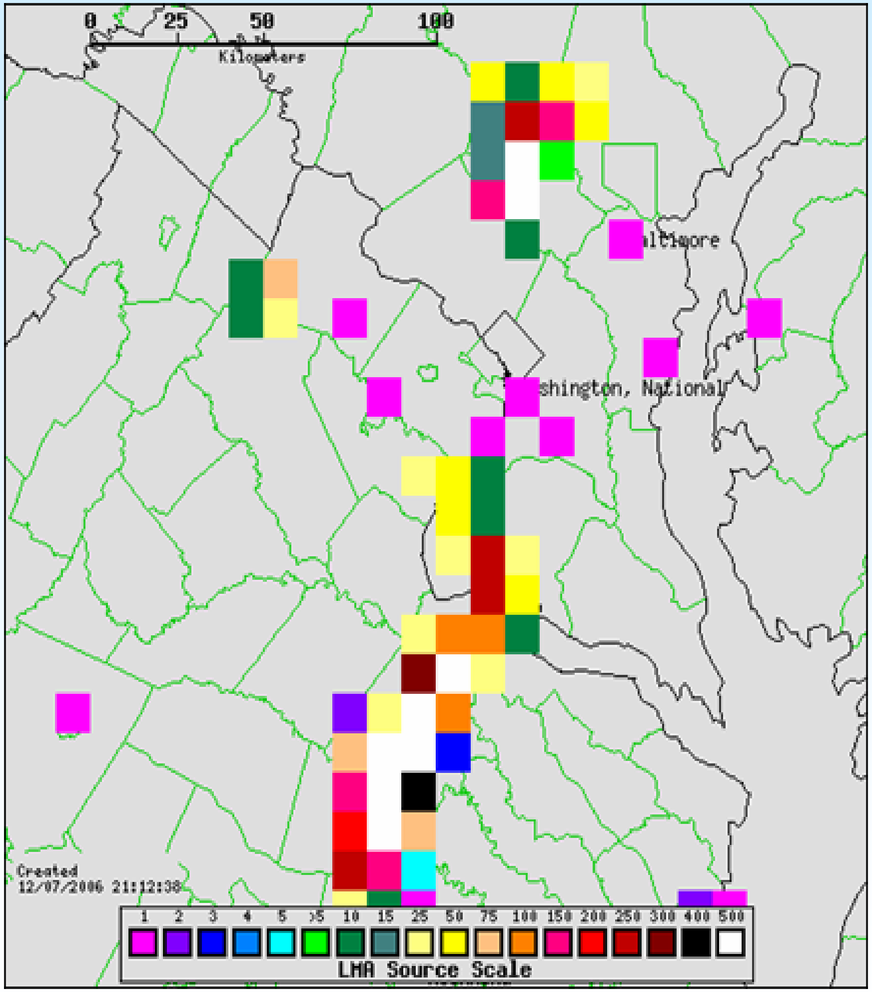


DC Regional Storms November 16, 2006

Resampled 5-min source density at 1 km and 10 km



LMA 1 km resolution



LMA 10 km resolution

Testing and Validation

Demonstrating Algorithm Performance…

- Truth data
  - » Ground-based lightning networks, in-situ
  - » Ancillary data
  - » Field Campaigns
  - » Hazardous Weather Testbed- Huntsville, AL and Norman, OK
- Algorithm Test plan
  - » Use proxy/simulated data cases
  - » Perform verification using truth data above in conjunction with proxy/simulated data cases to perform verification
- Error Estimation/Accuracy
  - » Validate against “heritage” ground truth sources above
  - » Metrics: Root Mean Square Error and Bias; POD, FAR, CSI for warning lead time
- Latency
  - » Evaluate run time
  - » Our goal is to process as much data as we can, identify bottlenecks and optimize in order to assess/address latency risks

Testing and Validation
Proxy and Simulated Data…

Proxy Data

- TRMM LIS/OTD- resampled to GLM resolution
- VHF total lightning- LMA remapped to GLM resolution
- SEVERI, MODIS as ABI proxies concurrent with LIS and ground-based lightning data- for merged ABI-GLM products

Simulated Data

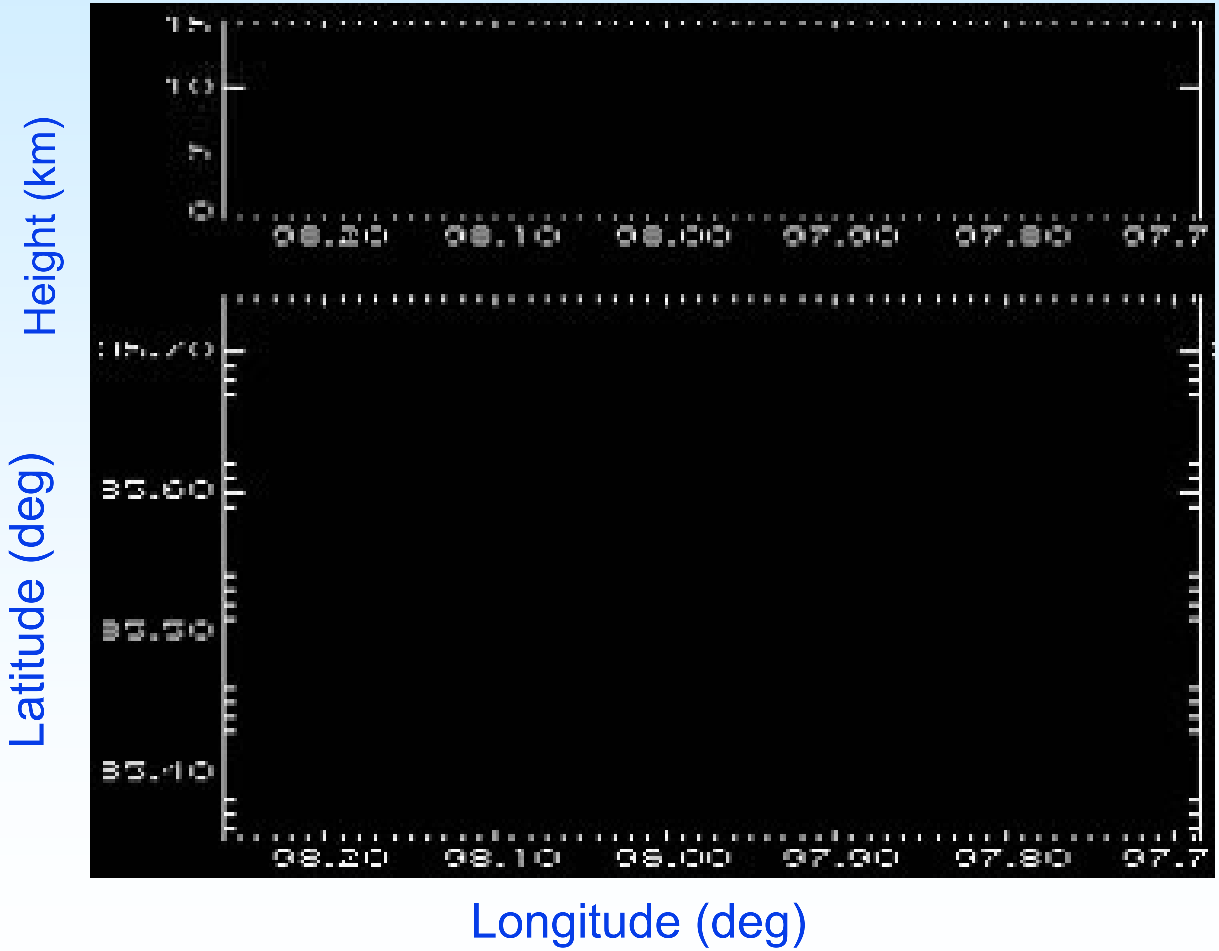
- WRF, RAMS, cloud resolving models

GOES-R Proving Ground:

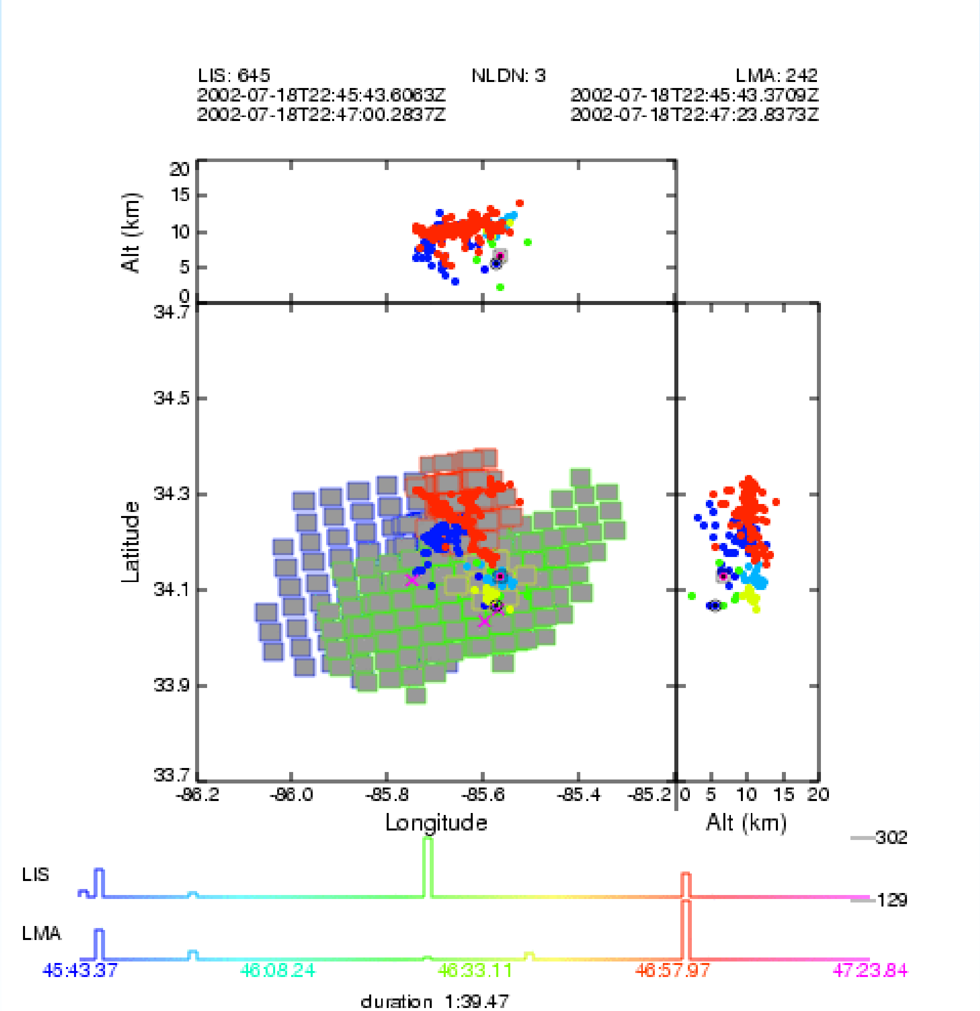
Proxy GLM and ABI data and products

LIS Validation

Lightning Discharge Observed Simultaneously by LIS and Ground-based VHF Lightning Mapping Array (LMA)



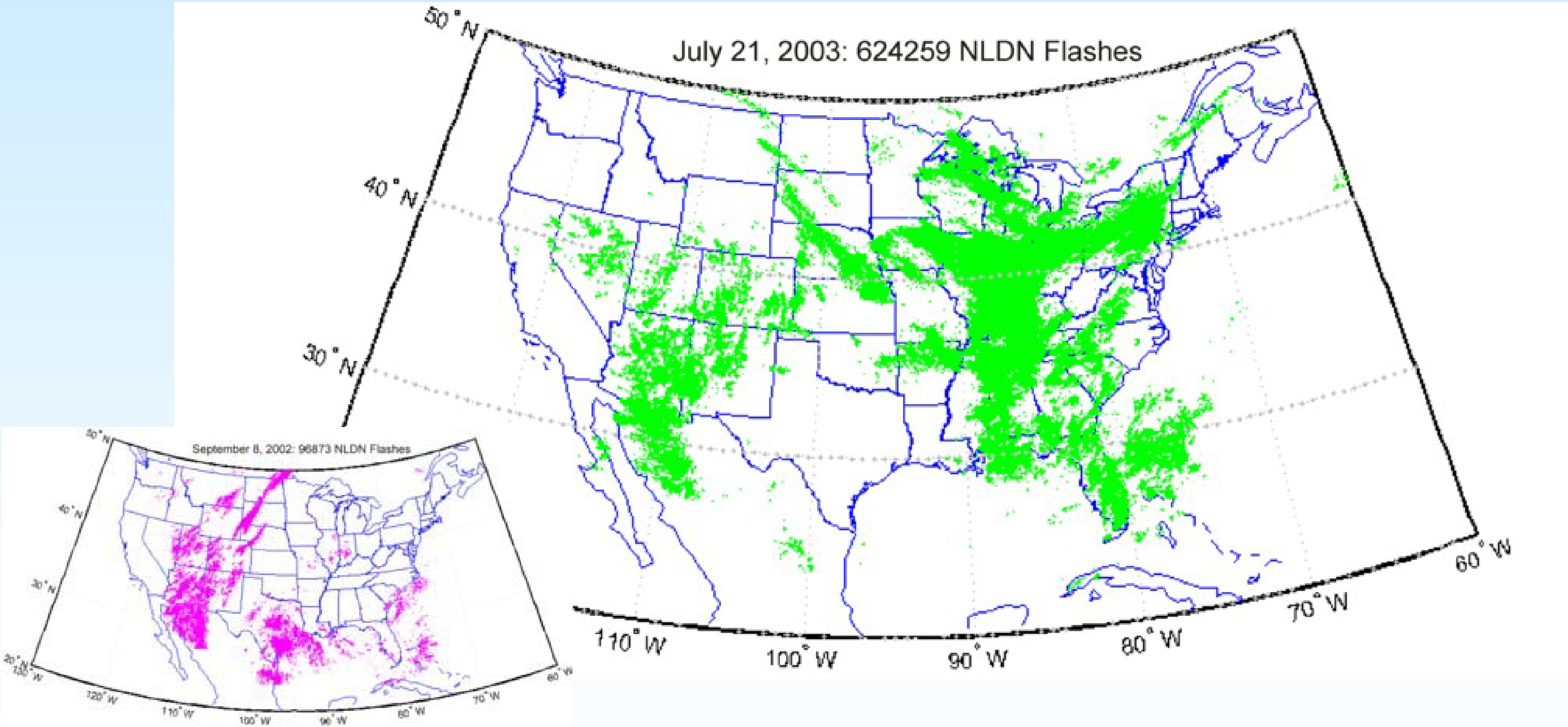
GLM Proxy Data



Tool developed to start inter-comparing LIS (squares), LMA (dots), and NLDN (Xs) for Proxy Data Development.

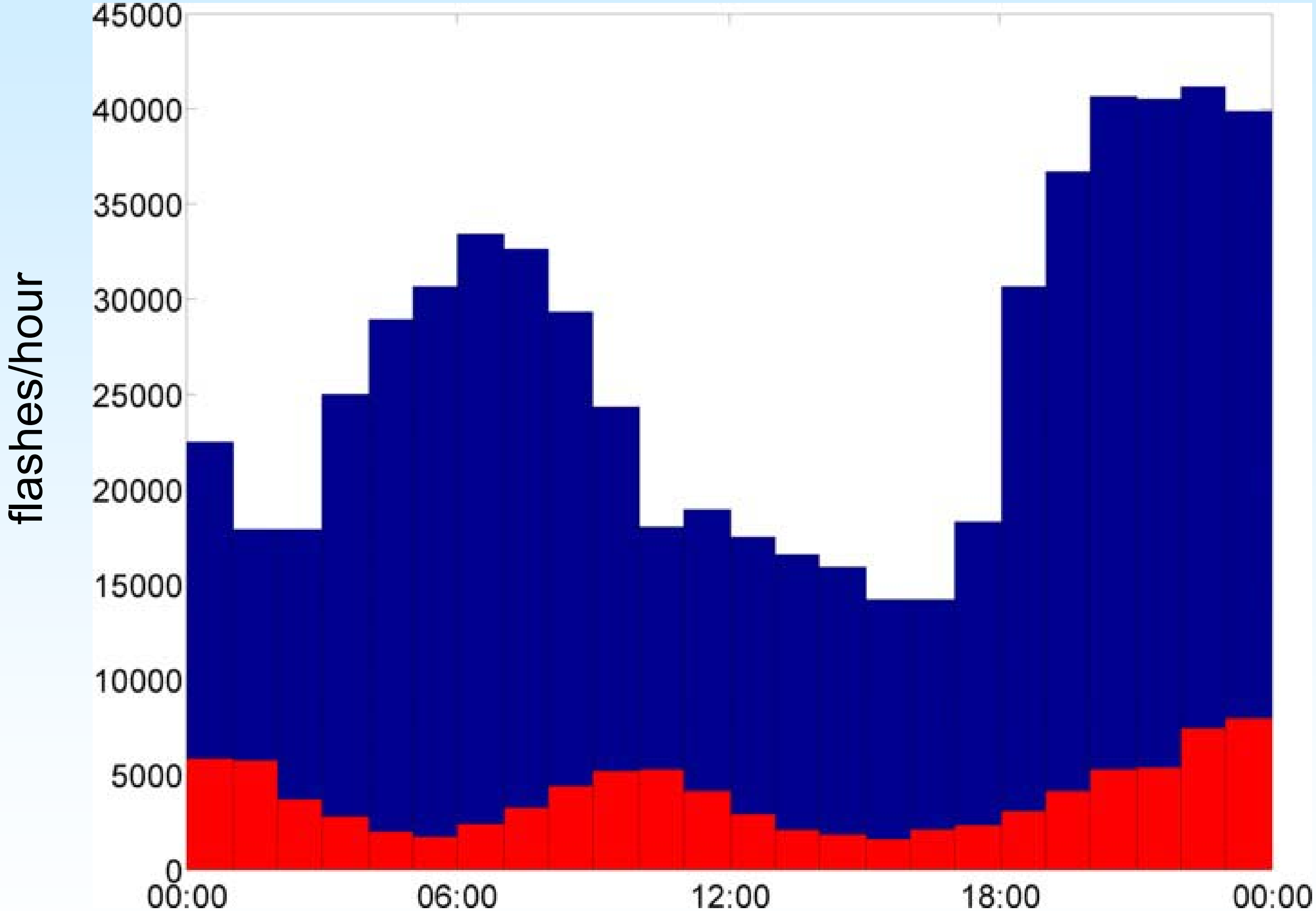
Courtesy of Monte Bateman

Regionalization Test Dataset



Since all we are testing is the regionalization code (no clustering), we do not need event-like data for this test. All we need is data that can be 'regionalized' and NLDN data works for that. Note that the day we chose (7-21-03, green) has more than 6X the NLDN lightning of a 'typical' day (e.g., 9-8-02, magenta).

Regionalization Test Dataset

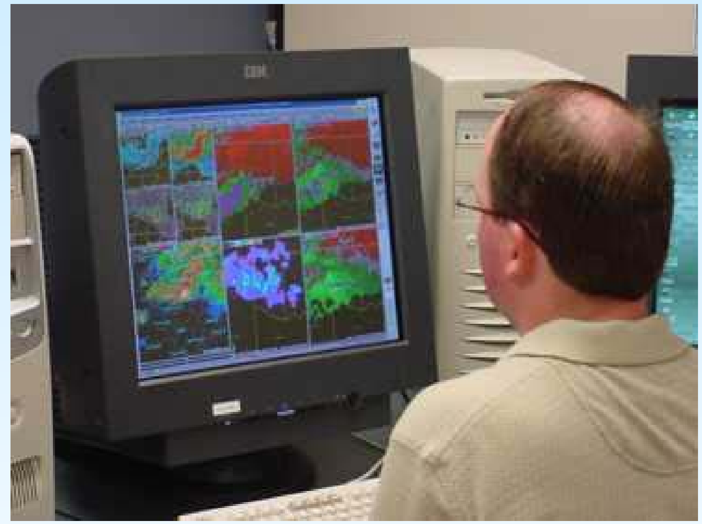


Hourly Flash Rate (flashes/hour)

Red: ‘Typical’ NLDN flash rate
Blue: Our test day NLDN flash rate

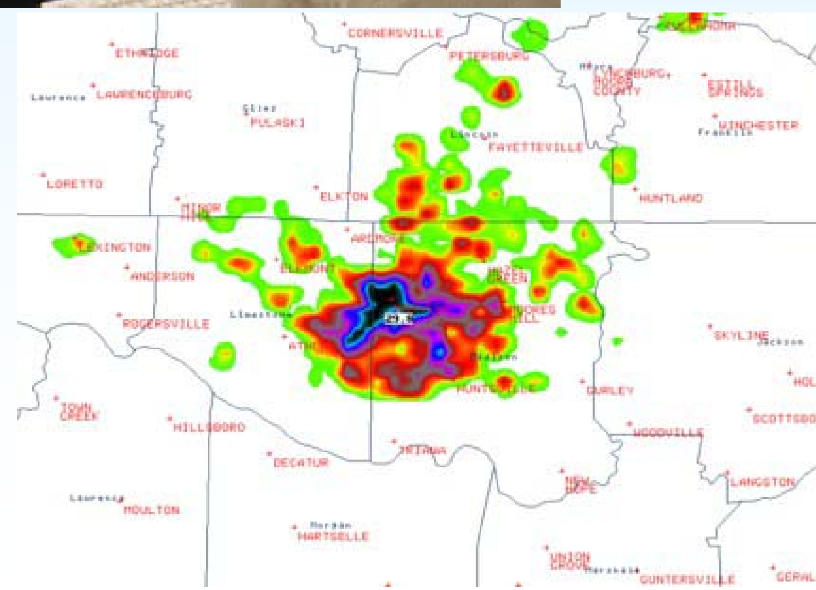
Total Lightning Impacts Decision Making

- **Has directly contributed to several correct severe warning decisions at HUN, OHX, and BMX.**



- ***"…the LMA density map gives you a great overall view of where storms with intensifying updrafts are located. So it gives you a good map of where to concentrate attention."***

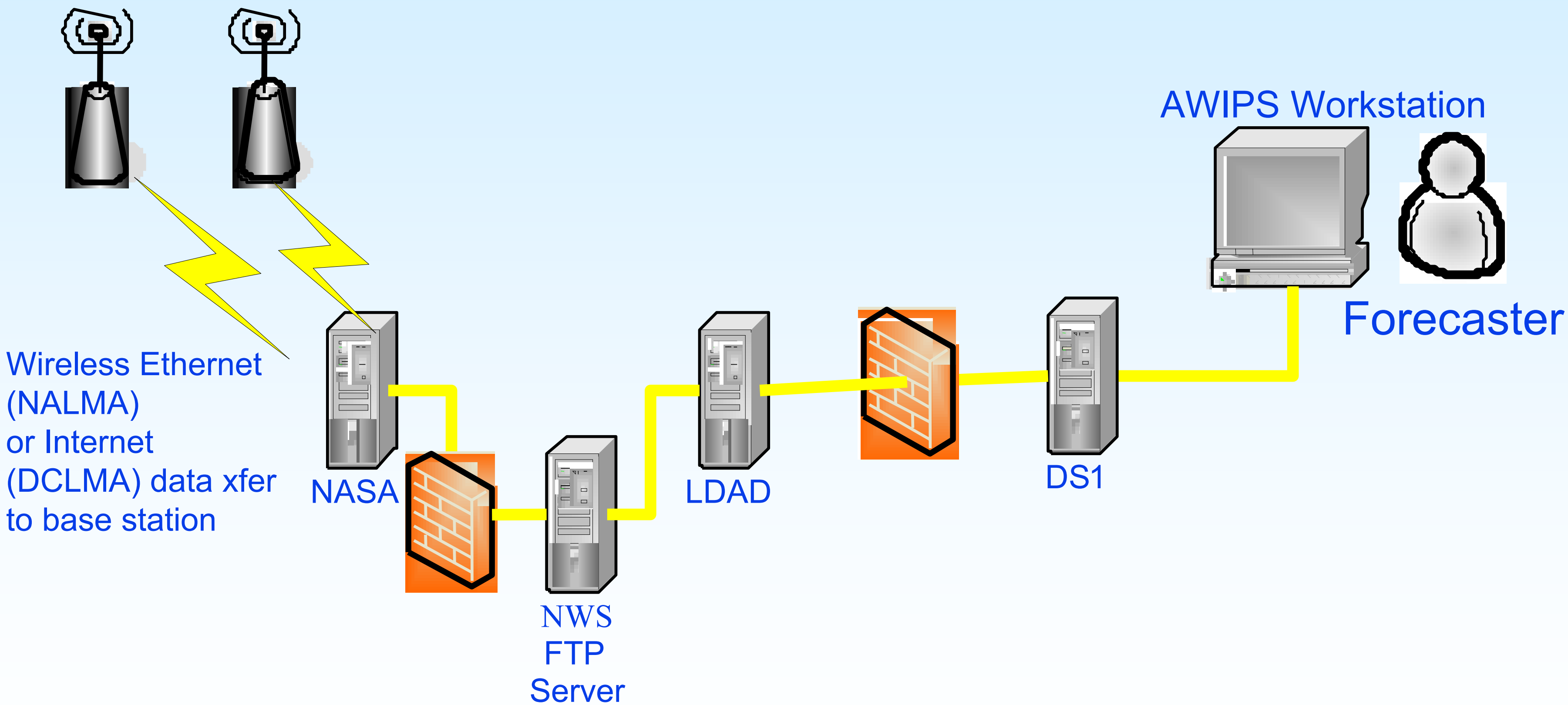
- ***"I believe the flash density rates were the primary factor in holding off on a warning."***



- **Data archived by WFO**

- **Used in Warning Event Simulator for office training**

LMA Ingest into AWIPS at the National Weather Service

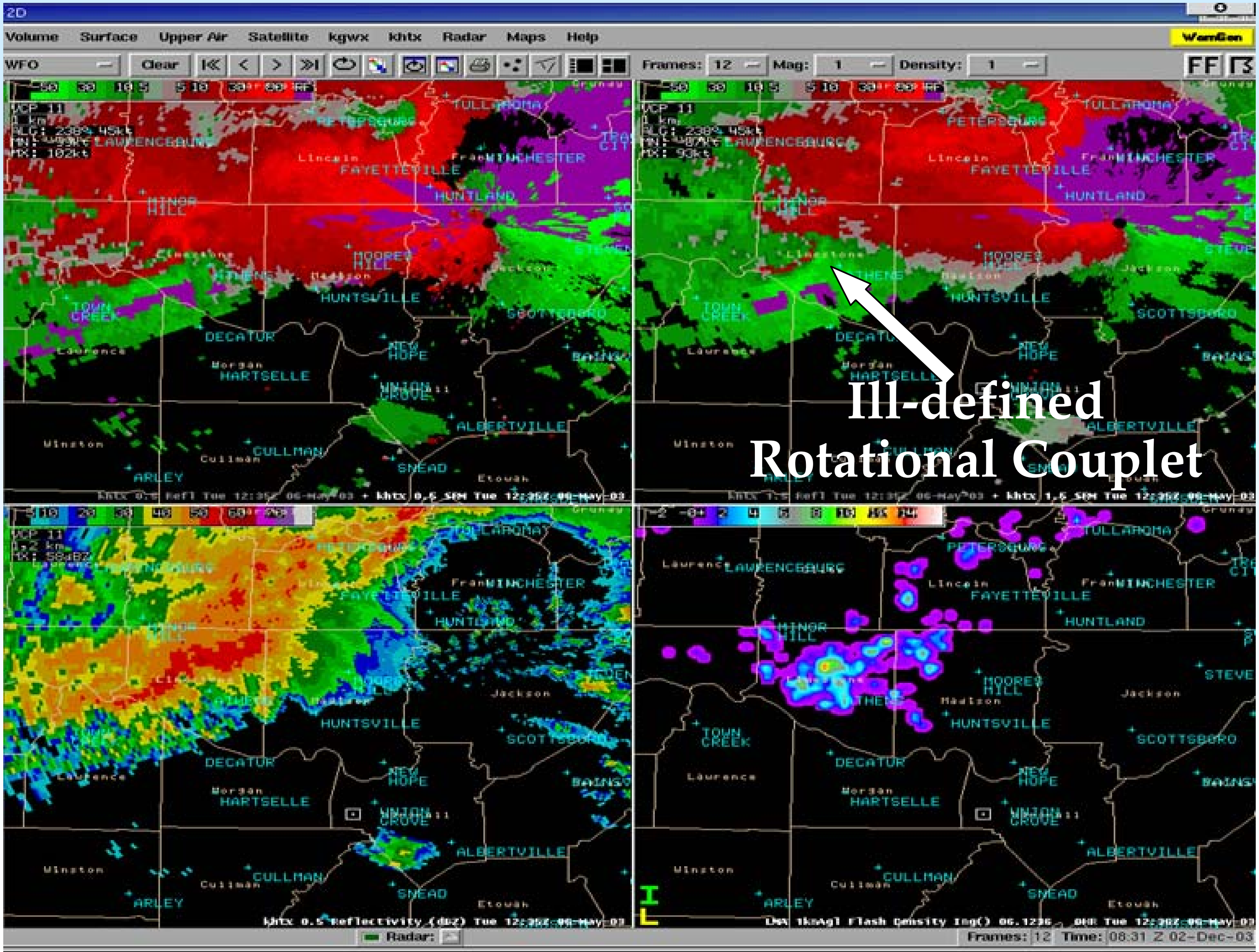


AWIPS- Advanced Weather Interactive Processing System

May 6, 2003 Case

0.5 º SRM

1.5º SRM

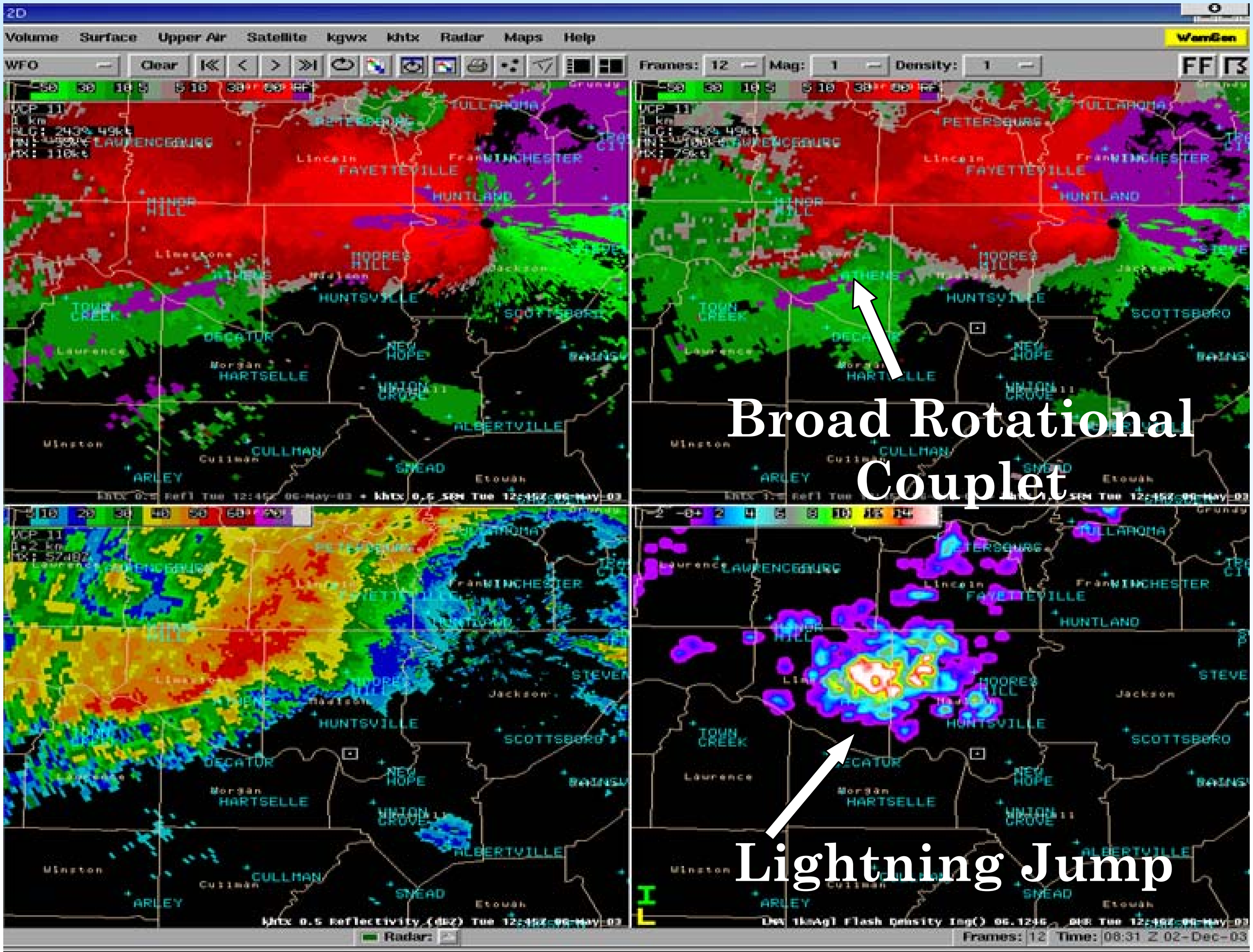


0.5 º Refl

LMA Source Density

North Alabama LMA

May 6, 2003 Case



North Alabama LMA

Forecast Usage

April 8 HUN Severe Wx - Chris Darden, NWS:

"...As for LMA during the warning process, it certainly did factor into the supercell that strengthened across northern Limestone/Madison Counties and then moved into southern Lincoln County. There was a very nice jump/surge with this one as the rotational couplet tightened. We noticed this in real-time during our "weather watch"..."

Total lightning has directly contributed to several correct severe warning decisions at HUN, OHX and BMX.

Forecast Usage

AREA FORECAST DISCUSSION
NATIONAL WEATHER SERVICE HUNTSVILLE AL
838 PM CDT TUE APR 18 2006

AFTER AN ACTIVE LATE AFTERNOON/EARLY EVENING...SUPERCELL CONVECTION HAS SHIFTED S AND DIMINISHED. GREAT CALL BY THE DAY SHIFT AT BRIEFING TIME...AS THE STATIONARY BOUNDARY THAT LAY ACROSS NE AL LIT UP QUICKLY AROUND 21Z. THE STRONGEST CELLS TRACKED SOUTH ALONG THE BOUNDARY AND DEVELOPED DEEPER ROTATION WITH TIME...AND EXHIBITED STRONG LMA SOURCE DENSITY SIGNALS DURING ROBUST UPDRAFT PERIODS ALSO SHOWN IN THE HIGH VIL/LRM3 REFLECTIVITY FIELDS. LOW LEVEL LAPSE RATES (0-2KM) WERE QUITE STEEP BASED UPON THE KBMX SOUNDING AT 00Z. SIG SVR PARAMETER WAS FAIRLY HIGH THIS EVENING ALONG THIS BOUNDARY TOO. EFFECTIVE DEEP LAYER SHEAR WAS UP TO 40-50KT...SO WITHIN THE ZONE FOR SUPERCELLS. LOW LEVEL SHEAR AND LOW LCLS WERE SOMEWHAT LACKING FOR TORNADOGENESIS.

LJA: Lightning Jump Algorithm Identifies Growth and Decay

Lightning use in nowcasting severe storms

Strawman "Lightning Jump" Algorithm (Gatlin and Goodman, 2006)

Use of VHF Lightning Mapping Array data (LMA source data currently ingested by AWIPS; SPoRT, NOAA HWT and GOES-R Global Lightning Mapper research)

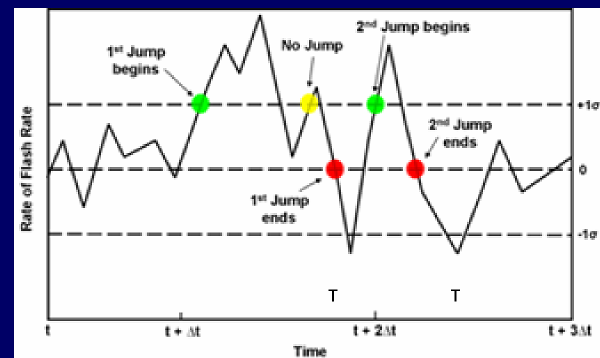
1. $\frac{d}{dt}(\mathit{flash\,rate})$ = DFRDT
2. $\sigma(DFRDT)$

DFRDT > +1σ

Lightning Jump

DFRDT < 0

Jump ends



- Physical basis: Updraft relationship to electrification
- Initial jump algorithm framework based on 20 severe multi/super cell cases
  - Promising results- POD 1, CSI .513, FAR .482
- Mean and standard deviation thresholds based on pre *and* post-event flash rate means.
- Continue ***physically-based*** extension/refinement and improvement of algorithm (i.e., FAR, CSI) for broad range of severe storms

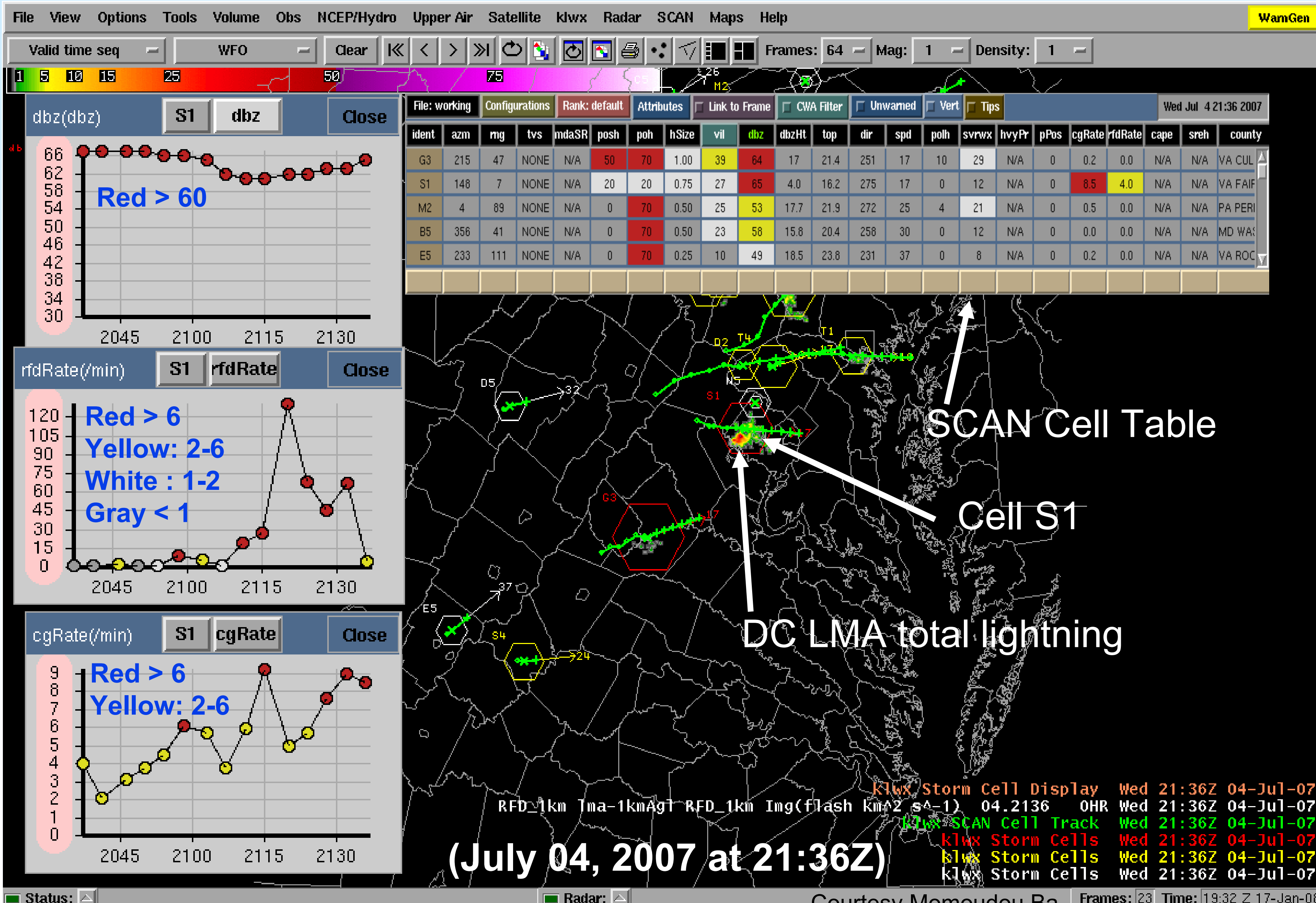
"Jump" Precedes tornado by 18-28 min, avg 17 min

POD- 0.818 FAR- 0.419 CSI- 0.514

P. Gatlin, April 2007, M.S. Thesis "SEVERE WEATHER PRECURSORS IN THE LIGHTNING ACTIVITY OF TENNESSEE VALLEY THUNDERSTORMS"

Lightning Jump Algorithm:

Experimental Trending Implementation in AWIPS/SCAN



ident	azm	rng	tvs	mdaSR	posh	poh	hSize	vil	dbz	dbzHt	top	dir	spd	polh	svrwx	hvyPr	pPos	cgRate	rfdRate	cape	sreh	county
G3	215	47	NONE	N/A	50	70	1.00	39	64	17	21.4	251	17	10	29	N/A	0	0.2	0.0	N/A	N/A	VA CUL
S1	148	7	NONE	N/A	20	20	0.75	27	65	4.0	16.2	275	17	0	12	N/A	0	8.5	4.0	N/A	N/A	VA FAIF
M2	4	89	NONE	N/A	0	70	0.50	25	53	17.7	21.9	272	25	4	21	N/A	0	0.5	0.0	N/A	N/A	PA PERI
B5	356	41	NONE	N/A	0	70	0.50	23	58	15.8	20.4	258	30	0	12	N/A	0	0.0	0.0	N/A	N/A	MD WAS
E5	233	111	NONE	N/A	0	70	0.25	10	49	18.5	23.8	231	37	0	8	N/A	0	0.2	0.0	N/A	N/A	VA ROC

Conclusions

Significance: The GLM offers a new capability to observe all lightning day and night and with near-uniform coverage of the US and adjacent oceans to improve NOAA's ability to issue forecasts and warnings that will save lives.

Summary and Next Steps

- Develop GLM proxy dataset for testing of GLM algorithms (filtering, clustering, cell tracking, lightning jump) under development.
- Transition heritage TRMM/LIS clustering & filtering algorithms to GEO.
- Continue upgrade of LMA networks, the evaluation of LMA data utility, and the improvement of associated training modules at WFOs.
- Develop cloud-resolving WRF model simulations to predict total lightning flash rates as a function of space & time.
- Jump Algorithm test at selected WFOs (Sterling, VA; Huntsville, AL; Norman, OK; Others)
- Continued AWIPS modifications to support algorithm prototyping- ATAN
- Investigate connections between precipitation processes, updraft strength, and lightning flash rate.
- Investigate the potential for discriminating ground & cloud flashes based on differences in their cloud-top optical characteristics.


Thank You